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Evaluation of Executive Jet Approach Angles

Frank Parr

April 1972
FINAL REPORT

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Flight Standards Service
Washington, D. C. 20591

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16. Abstract

Evaluations were flown in the Aero Jet Commander, Gates Lear Jet, North American Sabreliner, and Lockheed JetStar. Approach slope angles were varied from approximately 3 degrees up to almost 7 degrees. Flight parameters were measured in the areas of descent airspeed, power requirements in flare, flyability, sink rates, threshold crossing heights, and touchdown distances. Objective and subjective measurements were made. It was found that when approach slope angles above 4 degrees (approximate minimums of 400 feet altitude - 1 mile visibility) were used they were accompanied by problems of power requirement, flyability, high sink rates, and long touchdown distances.

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Project Report on Evaluation of Executive Jet Approach Angles

Project Officer	Frank Parr Technical Assistant, Standards Development Branch
Concur	E. E. Callaway Chief, Standards Development Branch
Approved	E. E. Blanchard Chief, National Flight Inspection Division
Released	Acting Director, Flight Standards Service

April 1972

INTRODUCTION

In 1966 an evaluation was performed to identify the maximum approach slope gradient which could be tolerated by light aircraft. This evaluation was documented in the final report of the Standards Development Branch, March 1966, "Project Downhill. An Evaluation of the Non-precision Approach Angles for Light Aircraft with Approach Speeds Less than 95 Knots."

The joint DOD-DOT Handbook "United States Standard for Terminal Instrument Procedures (TERPs)" * is scheduled for regular review to update and refine standards. Information similar to that derived from Project Downhill is considered to be essential to the development of TERPs non-precision approach minimums which apply to executive jet type aircraft. Accordingly, a follow-on evaluation was requested which would provide that information. This is the final report of the project which was established to accomplish the task.

* U. S. Army TM 11-2557-26. U. S. Navy OPNAV Inst. 3722.16A
USAF JAFM 55-9 USCG CG 318
FAA Handbook 8260.3

Figure 1. Will Rogers World Airport

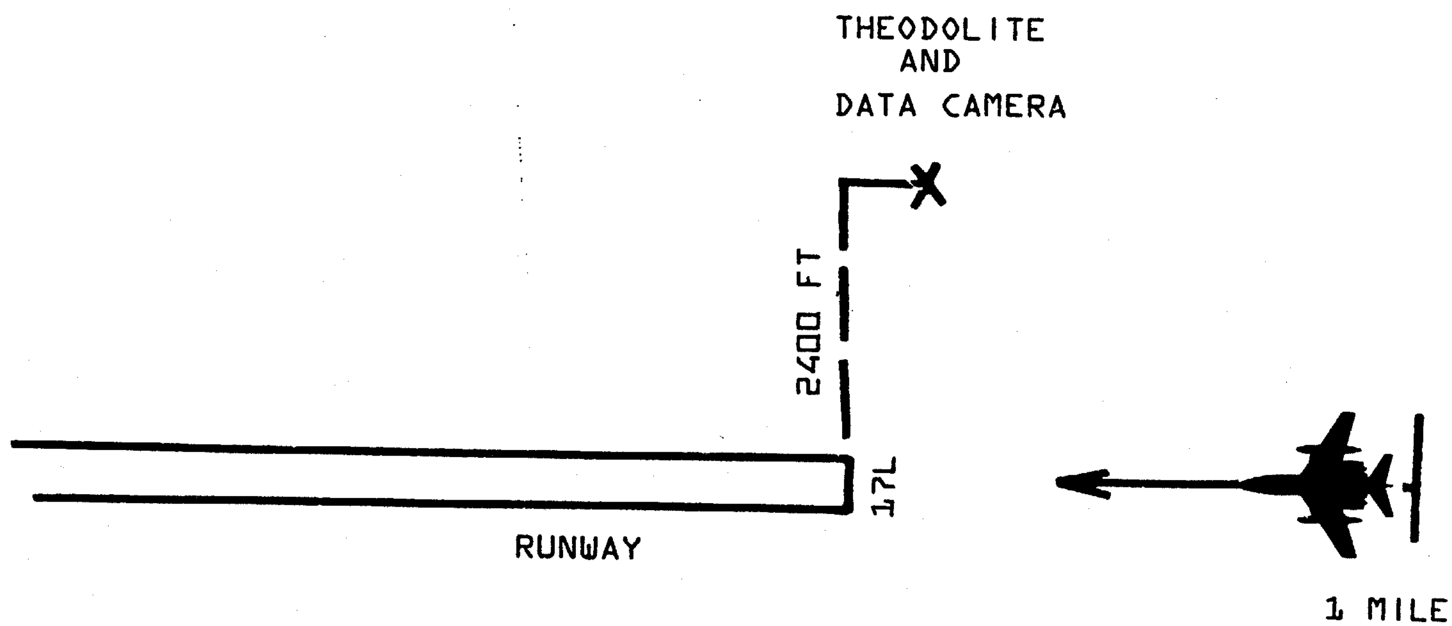


Figure 2. Data Camera and Theodolite Location

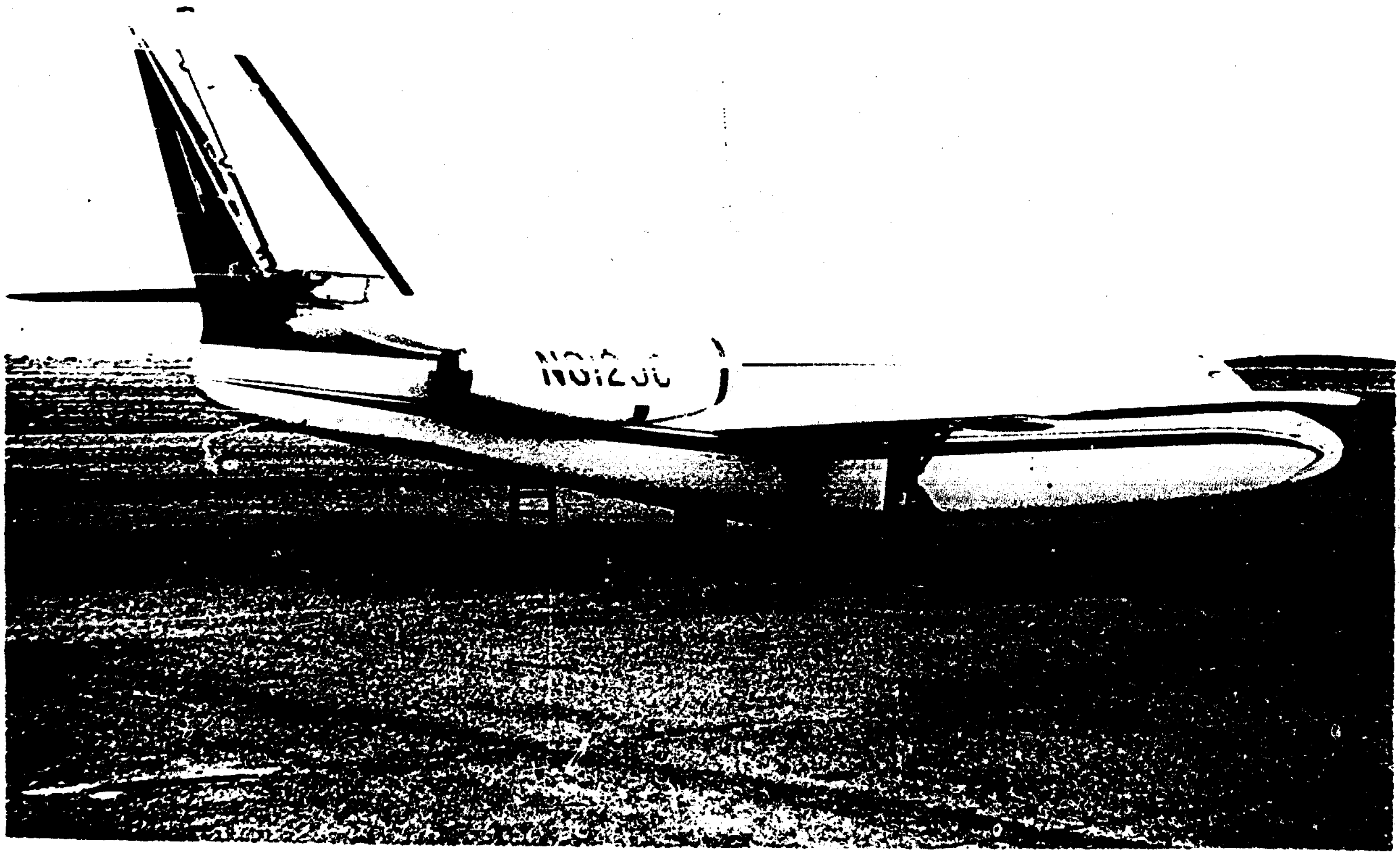
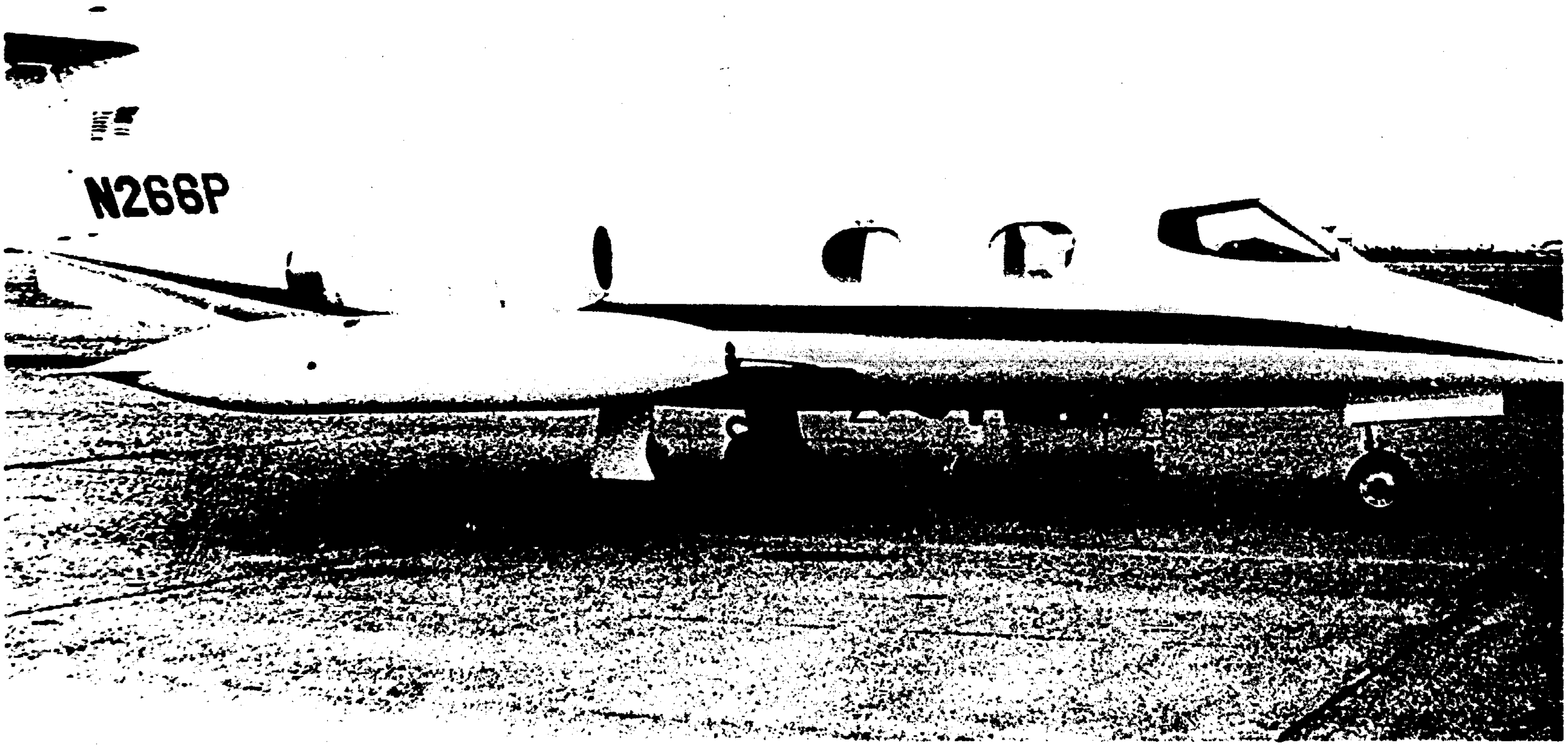


Figure 3. Test Aircraft - Aero Jet Commander



Test Aircraft - Gates Lear Jet

Figure 5. Test Aircraft - North American Sabreliner

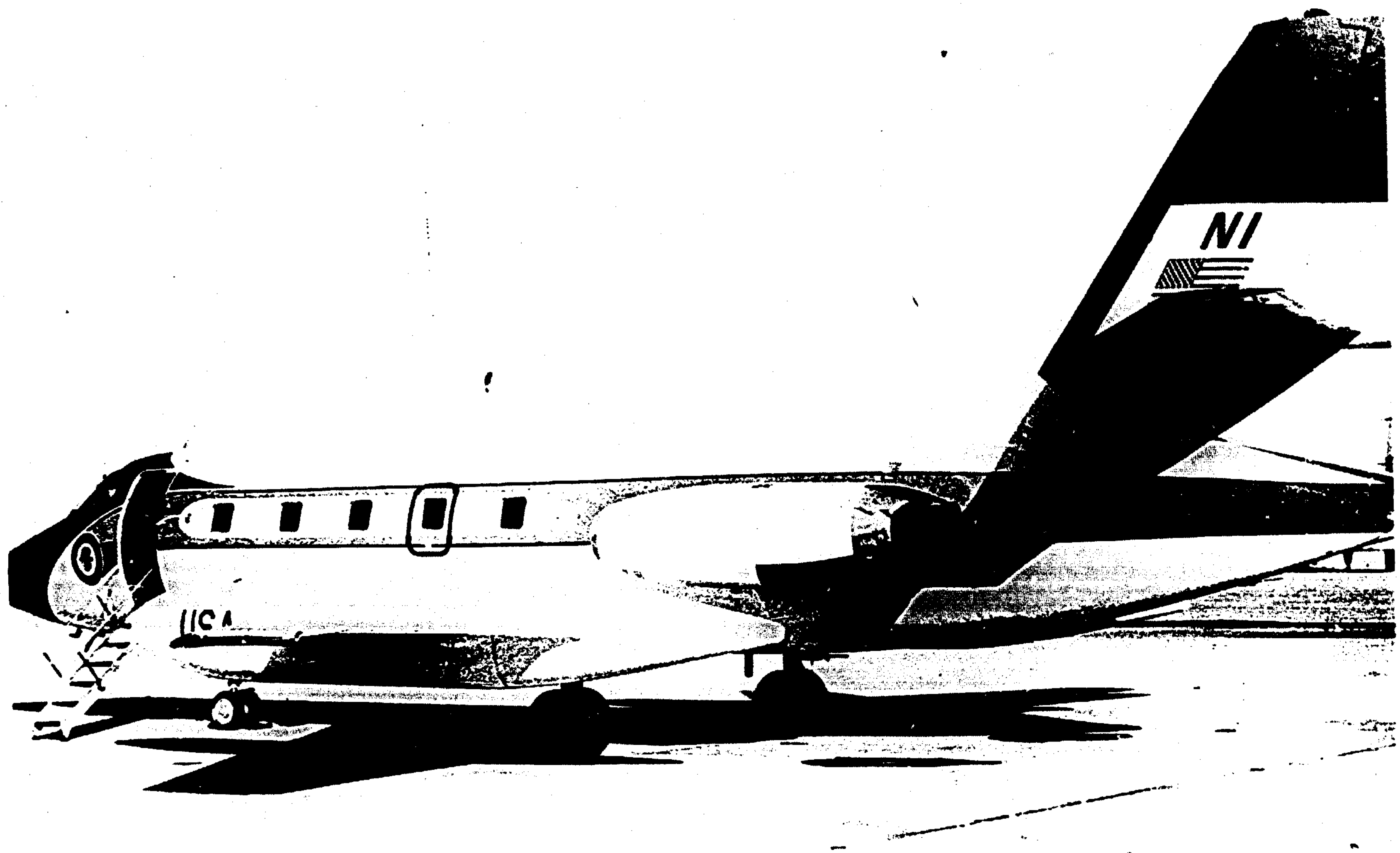


Figure 6. Test Aircraft - Lockheed JetStar

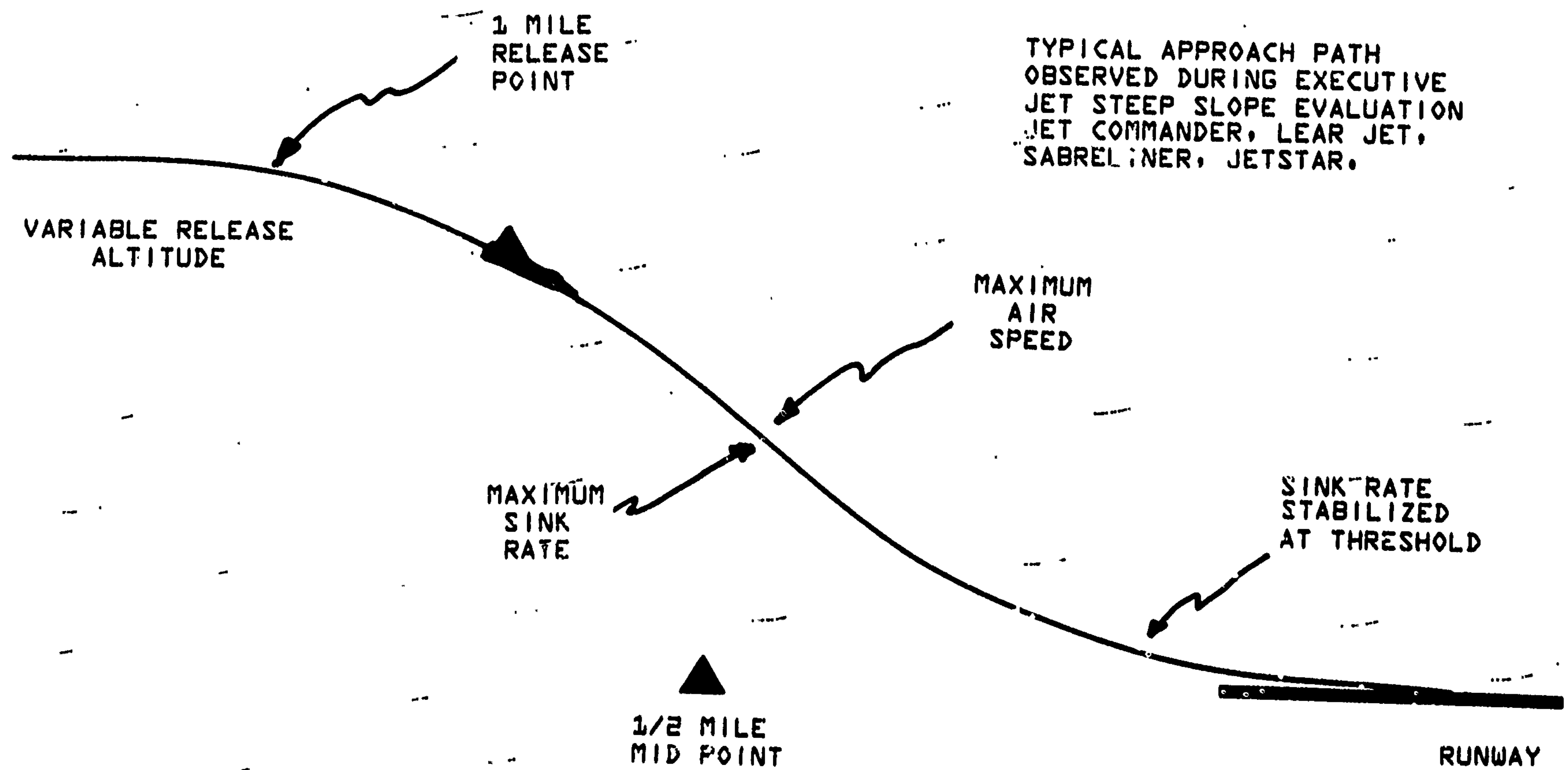


Figure 7. Typical Approach Path.

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Jet Commander

Jack P. Ervin, AC-958
Richard A. Fournier, AC-958
E. E. Callaway, FS-640

Lear Jet

Richard W. Blondefield, AC-958
J. Lee Jarvis, AC-958

Sabreliner

Charles L. Hall, FS-620
L. F. Abernathy, FS-620
Earl L. Rowe, FS-620
James H. McMaster, FS-620

Jetstar

John Newell, EA-GADO-16 Richmond
Douglas B. Moore, SO-GADO-1 Atlanta
John T. Crouse, FS-754

Observers

Norman C. Heidger, FS-640
Allan W. Hunting, NE-GADO Norwood

Electronics Specialists

Russell S. Fleming, FS-640
Robert C. Chadwick, FS-640

Oklahoma City Airport Trust

John D. Solomon, Airports Director
R. F. Traub, Airports Engineer

Air Traffic Service

Howard H. Murphy, OKC Rapcon/Tower

STATEMENT OF THE PROBLEM

Approach procedures are designed to assure a landing on each approach. An unreasonable descent rate from the visual contact point cannot, therefore, be required in a procedure. Tests have been made of the descent capability of heavy jet and prop aircraft, and of light prop aircraft. None have as yet been documented which identify the descent capability of the group of aircraft categorized as "executive jets".

OBJECTIVES

The objective of this study is to provide information on the descent slope capability of executive jet aircraft. Tests will include the Aero "Jet Commander", the Gates "Lear Jet", the North American "Sabreliner", and the Lockheed "Jetstar". Specific areas of study include:

1. Determine the operational safety and practicality of descent angles over 3 degrees during the visual portion of a non-precision approach.

2. Determine the effect of increased approach angles on descent airspeed, flare, flyability, sink rates, height over the threshold, and touchdown distance.

METHODOLOGY

The test site was Will Rogers World Airport, Oklahoma City, Oklahoma. Runway 17L was used for all approach runs.

Each series of runs began at 300 feet above the threshold, with pilots making a run "on centerline" toward the runway. As the aircraft reached a point one statute mile from the runway threshold, a ground controller using a precision theodolite for position reference transmitted the word "release" to the pilot. The pilot then executed a visual approach to landing using normal procedures for the aircraft.

Data were recorded using the Runk Takeoff and Landing Camera and by an observer in the aircraft.

After the run at 300 feet, the pilot was asked to fly the same approach at 400, 500, 600, etc., feet above the runway threshold height until the limits of the aircraft/pilot were

reached. In some cases additional runs were made at levels 50 feet below the maximum level to check in-between angles.

Preliminary runs were made to full-stop landings to check ground roll, but most runs were touch-and-go landings. Day and night approaches were made.

Sixty-three approaches were recorded in the four aircraft by twelve qualified pilots. Thirty-eight runs were made during daylight, and twenty-five were flown at night. One run was forced to discontinue because of conflicting traffic, and was therefore unusable.

Pilot comments were solicited during each approach.

DATA REDUCTION AND ANALYSIS

Several measurements were used in an attempt to define the point at which an approach slope angle becomes difficult. An objective view of maximum angle was thus made possible. The measurement parameters were as follows:

Condition	Tolerance Limit
Airspeed during descent	V_{ref} plus 5 knots.
Flare	Power not required.
Flyability	No special techniques. Pilot comments favorable.
Maximum sink rate	1000 feet per minute.
Sink rate at threshold	1000 feet per minute.
Threshold crossing height	20 to 60 feet.
Touchdown distance	2000 feet.

All data were taken from cockpit instrument readings with the exception of threshold crossing height, which was read from Runk data camera film. Readings were tabulated, and are seen on Pages A1 and A2 of the Appendix.

Actual approach angles were computed as follows:

1. The "set" descent gradient was computed using the distance to the threshold and height above desired touchdown point at the release point.

2. The "effective" gradient was established by correcting for wind using the formula:

   $$\text{Effective Gradient} - (\text{set gradient X } \frac{\text{ground speed}}{\text{airspeed}})$$

3. Effective gradient was converted to approach slope angle.

Effect of Approach Angle on Descent Airspeed

Jet Commander. Airspeed ranged from V-ref to 10 knots above V-ref, but no correlation can be seen between the change in airspeed and the change in descent angle. See Chart 6, Appendix Page A-3.

Lear Jet. Airspeed ranged from V-ref to 10 knots above V-ref with no apparent correlation between changes in speed and changes in angle. See Chart 7, Appendix Page A-4.

Sabreliner. Airspeed ranged from V-ref to 15 knots above V-ref. Airspeed in descent increased generally with increase in approach angle. See Chart 8, Appendix Page A-5.

Jetstar. Airspeed remained very close to V-ref on all runs. See Chart 9, Appendix Page A-6.

All Data. Airspeeds of all aircraft are plotted together on Chart 10, Appendix Page A-7. Except for data recorded by the Sabreliner, high airspeeds on final approach did not appear to occur increasingly as approach angles were increased. One point is apparent, however; closer control over descent airspeed was maintained during the night runs. Only one out-of-tolerance airspeed occurred during night runs while many were recorded during day operations. See Appendix Page A-2 and Charts 42 and 43, Appendix Pages A-39 and A-40.

Effect of Approach Angle on Requirement for Power to Flare.

Jet Commander. At 3.5 degrees the requirement for power in flare began. It became necessary on over 50 percent of the runs at 4 degrees and over. See Chart 11, Appendix Page A-8.

Lear Jet. At 4 degrees nearly 70 percent of the runs required power to flare. Over 4 degrees the requirement went to 100 percent. See Chart 12, Appendix Page A-9.

Sabreliner. The power requirement began at 5 degrees. See Chart 13, Appendix Page A-10.

Jetstar. One power application was made at approximately 4 degrees, and considerable power was required at angles above 6.5 degrees. See Chart 14, Appendix Page A-11.

All Data. The power requirement in flare shows a sharp increase at 4 degrees and this requirement remains at higher angles. See Chart 15, Appendix Page A-12.

Effect of Approach Angle on Flyability.

Jet Commander. Moderate difficulty occurred at angles of 3.5 and 4.5 degrees. See Chart 16, Appendix Page A-13.

Lear Jet. No special difficulty below 5 degrees. See Chart 17, Appendix Page A-14.

Sabreliner. No flyability problems up to 6.5 degrees. At higher angles exceptional techniques were required to effect a landing. See Chart 18, Appendix Page A-15.

Jetstar. Angles above 4 degrees were generally considered by project pilots to be acceptable if the approach is to be conducted under VFR conditions. See Chart 19, Appendix Page A-16.

All Data. See Chart 20, Appendix Page A-17. Flyability problems began at 3.5 degrees, but did not affect most aircraft until angles went above 4 degrees. Comment of subject pilots indicated that when the aircraft was equipped with thrust reversers and anti-skid brakes higher approach angles were of less concern than to pilots of less sophisticated aircraft.

Effect of Approach Angle on Maximum Sink Rate.

Jet Commander. Most approaches resulted in sink rates over 1000 feet per minute. The majority of the high readings were observed at approach angles over 4 degrees. See Chart 21, Appendix Page A-18.

Lear Jet. As approach angles increased, so did maximum sink rates. Most runs at angles over 4 degrees resulted in sink rates over 1000 feet per minute. See Chart 22, Appendix Page A-19.

Sabreliner. Maximum sink rates increased as approach angles increased. Above 4 degrees all approaches resulted in sink rates which were out of tolerance. See Chart 23, Appendix Page A-20.

Jetstar. Rates increased with approach angles. All runs exceeded the tolerance when angles were above 4 degrees. See Chart A-24, Appendix Page A-21.

All Data. Up to a 4 degree approach slope angle only 20 percent of the runs had maximum sink rates over 1000 feet per minute. Over 4 degrees 98 percent were out of tolerance. Sink rates in general increased as approach angles increased. See Chart 25, Appendix Page A-22.

NOTE: Maximum sink rate occurred at or near a point 1/2 mile out from the landing threshold.

Effect of Approach Angle on Threshold Sink Rate.

Jet Commander. Over 70 percent of the runs had threshold sink rates within tolerance. Sink rates increased with the approach angle increases. See Chart 26, Appendix Page A-23.

Lear Jet. Above 4 degrees the threshold sink rate was out of tolerance on most runs. In general, sink rate increased as approach slope angles increased. See Chart 27, Appendix Page A-24.

Sabreliner. Sink rate increased with increases in approach slope angle. Threshold sink rate appeared more controllable in this aircraft than in the Jet Commander and Lear Jet, and it was kept within tolerance at angles up to 6 degrees. See Chart 28, Appendix Page A-25.

Jetstar. Threshold sink rate was closely controlled. Only one approach had out of tolerance sink. All others remained well below the tolerance limit. See Chart 29, Appendix Page A-26.

All Data. The general trend was for increases in approach slope angle to result in increases in threshold sink rates. Above 4 degrees the threshold sink rates went to 1300-1400 feet per minute. See Chart 30, Appendix Page A-27.

Effect of Approach Angle on Threshold Crossing Height.

Jet Commander. No significant correlation is apparent between TCH and approach angle. Height was above the upper

limit at angles above 3.5 degrees. See Chart 31, Appendix Page A-28.

Lear Jet. Above 4 degrees some TCH values went out of tolerance. These values were apparently not correlated with increases in approach slope angle. See Chart 32, Appendix Page A-29.

Sabreliner. More runs had TCH values below the 20 foot lower limit than above the 60 foot upper limit. No significant or apparent correlation between TCH and approach slope angle. See Chart 33, Appendix Page A-30.

All Data. Threshold crossing heights do not appear to be correlated with approach slope angles. 13 percent were low and 26 percent were high. Low readings occurred from 3.5 to 6.7 degrees. High readings occurred from 3.5 to 6.2 degrees. See Chart 34, Appendix Page A-31.

Approach Slope Effect on Touchdown Distance.

Jet Commander. A general trend can be seen indicating that higher approach angles result in longer distances for touchdown. Some touchdowns were beyond the 2000 foot tolerance at lower angles (to 3.5 degrees), but MOST exceeded the tolerance when the approach slope angle was increased to 4 degrees and over. See Chart 35, Appendix Page A-32.

Lear Jet. There was an increase in touchdown distance as the approach angles were increased. As the angle went above 4 degrees the touchdown distance increased out of tolerance. See Chart 36, Appendix Page A-33.

Sabreliner. As approach angles increased there was a general increase in touchdown distance. While one sample was outside at 3.5 degrees, most were still within tolerance at angles up to 5 degrees. See Chart 37, Appendix Page A-34.

Jetstar. No touchdown distances in this aircraft were out of tolerance, even though the approach slope angles were above 6.5 degrees. There were indications that higher angles result in longer touchdown distances. See Chart 38, Appendix Page A-35.

All Data. There is a general trend toward longer touchdown distances with higher approach slope angles as shown in the data distribution on Chart 39, Appendix Page A-36. The trend becomes suddenly stronger at approximately 4 degrees. Below 4 degrees less than 17 percent were out of tolerance, while above 4 degrees over 50 percent were out.

Night versus Day Approaches.

Charts 40 through 43, Appendix Pages A-37 through A-40, show runs during which conditions were out of tolerance, with the run identified as to whether it was made during day or night operation. No in-tolerance conditions are plotted on these charts.

During daylight operation, pilots accepted higher angles than they did at night. Only two night approaches were made at approach slope angles above 5.5 degrees, as opposed to 11 day runs. Highest night angle was just over 6.0 degrees, while day angles went almost to 7 degrees.

During night operation only one airspeed went out of tolerance as opposed to 13 instances during day operation, some at angles of 4 degrees and below. This means that in the absence of outside visual cues, there is some apparent increase in reliance on airspeed to provide approach information to the pilot.

Early Set. (Establish Landing Configuration Prior to 1 Mile).

Normal operating procedures in the Jet Commander and the Lear Jet involve waiting until a landing is assured before setting up in landing configuration. This resulted in airspeeds 20 knots above Vref at the one-mile-out release point. On some of the approaches landing configuration was set up early (at a point prior to reaching the release point) to determine whether a significant change in operating limits would result. As expected, having the airspeed stabilized at Vref prior to the release point resulted in an easier and more confortable approach in both aircraft. Pilots of the Jet Commander accepted approach angles nearly one degree higher when this method was used. They also did NOT identify even night approaches above 5 degrees as having flyability problems using this technique when some approaches made using the normal technique were deemed problems at just over 4 degrees.

Altimeter reading versus Actual Aircraft Height.

With threshold altimeter readings logged in the cockpit for comparison with actual aircraft height recorded with the Runk Data Camera, it was possible to check these differences. See Charts 44 through 47, Appendix Pages A-41 through A-44. Only 5 approaches showed indicated altitude to be at or lower than the actual aircraft height. All other approaches had cockpit indications of altitude higher than the actual height at the threshold. Differences were as much as 130 feet.

Summation of Conditional Parameters.

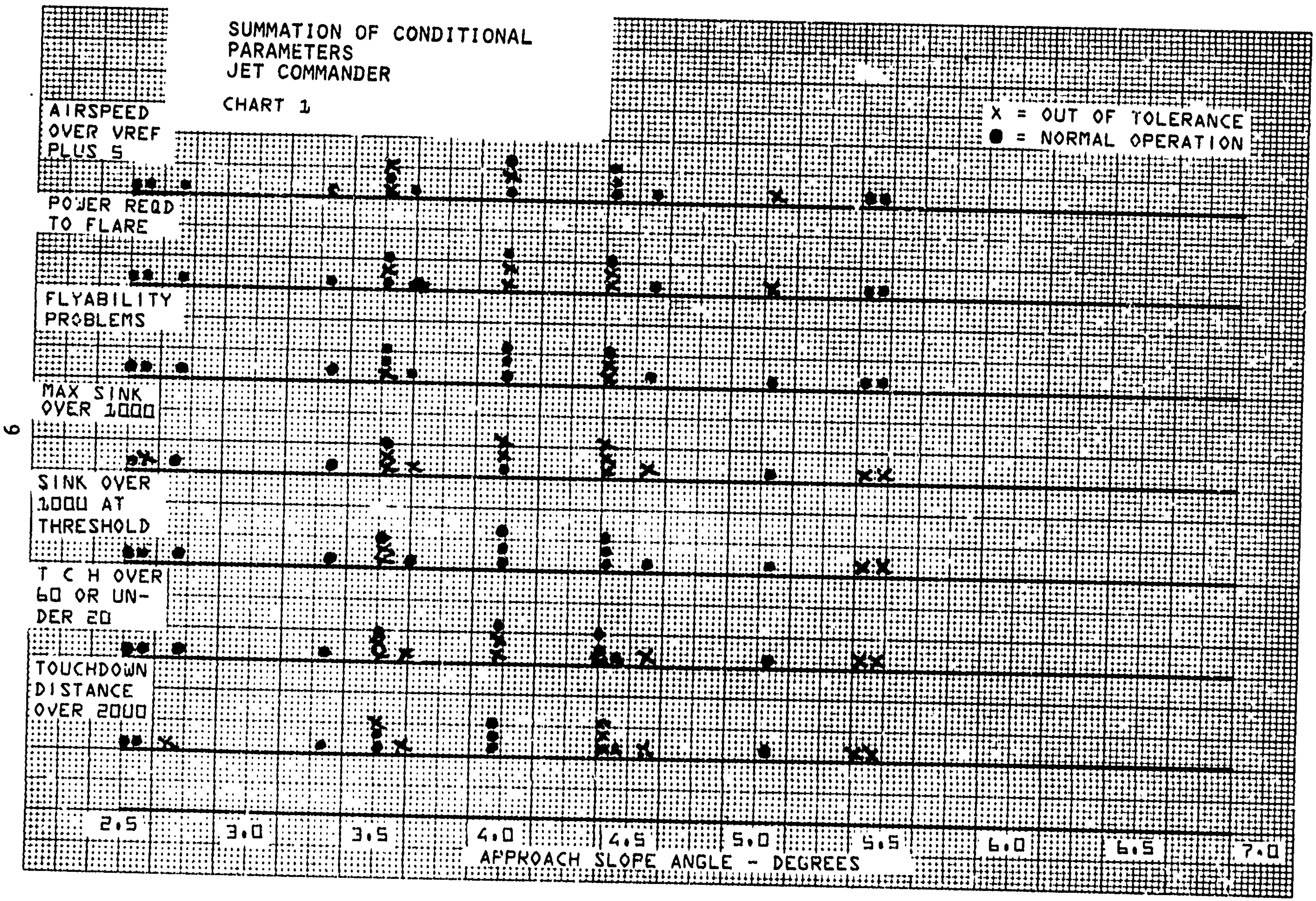
Jet Commander. Chart 1, Page 9, shows a summation of out of tolerance conditions. Problems began at 3.5 degrees and became prevalent at 4 degrees.

Lear Jet. Chart 2, Page 10 shows that out of tolerance conditions began at 4 degrees.

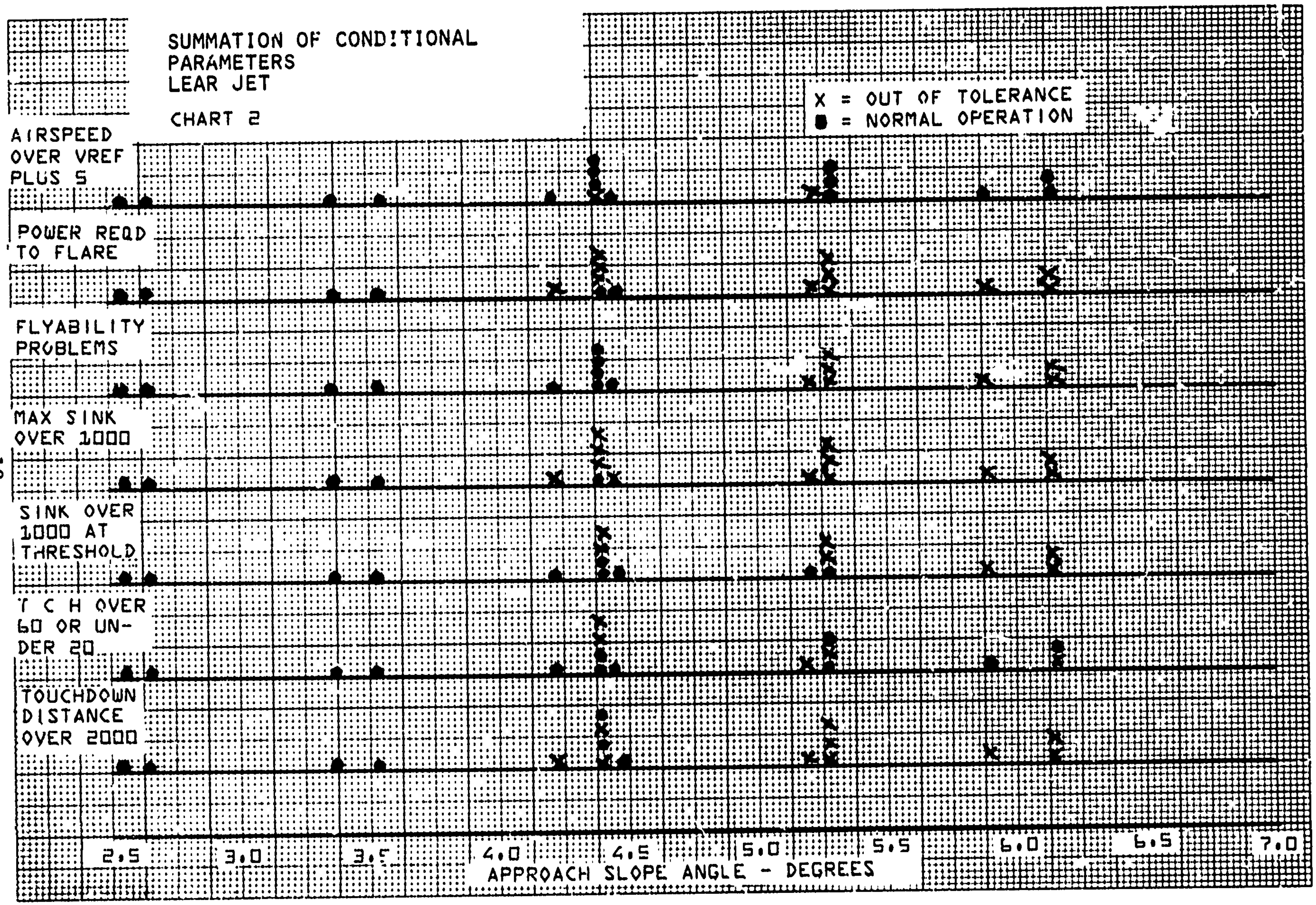
Sabreliner. Chart 3, Page 11. Out of tolerance situations occurred at 3.5 degrees, then increased markedly at and over 4 degrees.

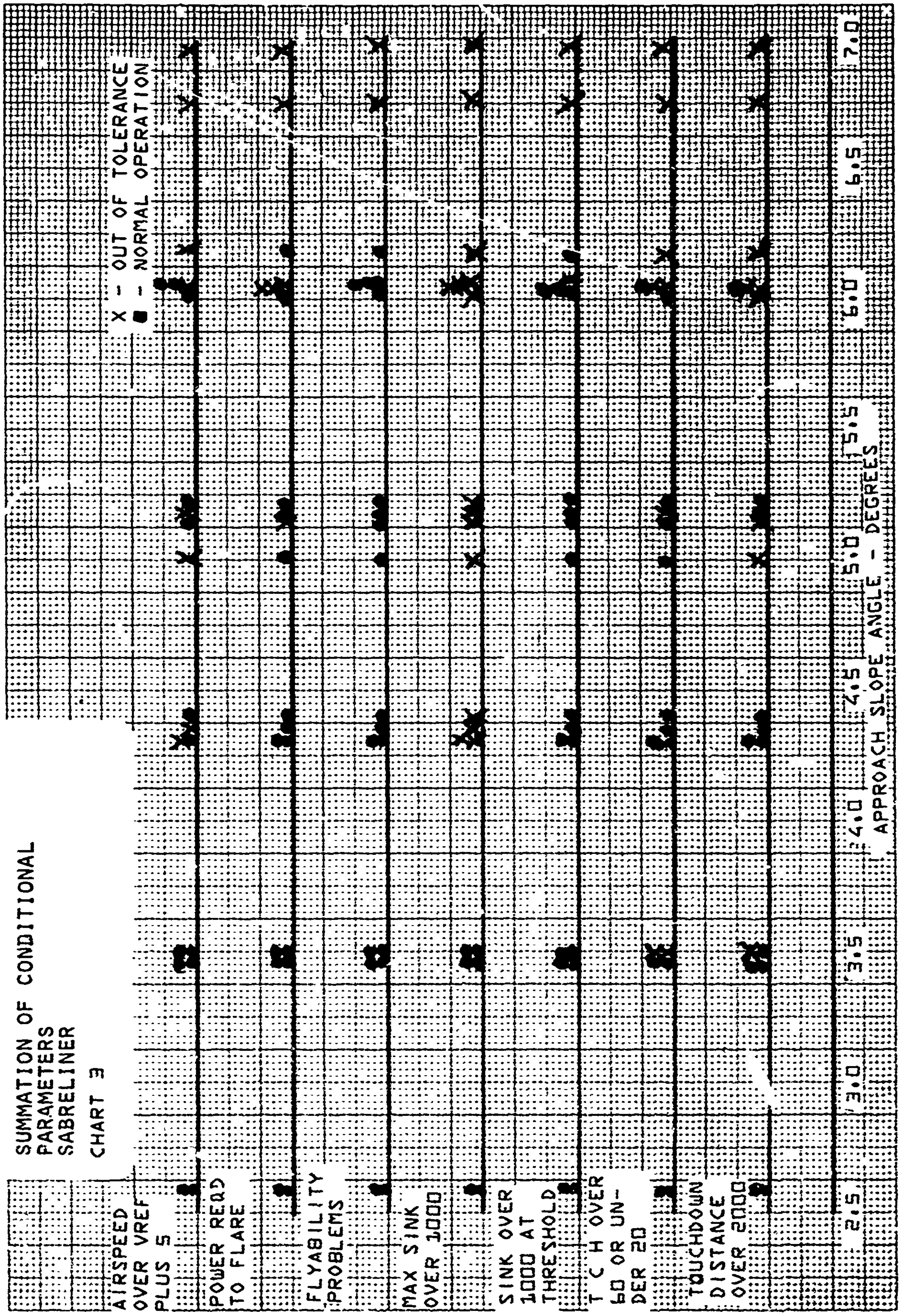
Jetstar. Chart 4, Page 12. Out of tolerance conditions began at 4 degrees.

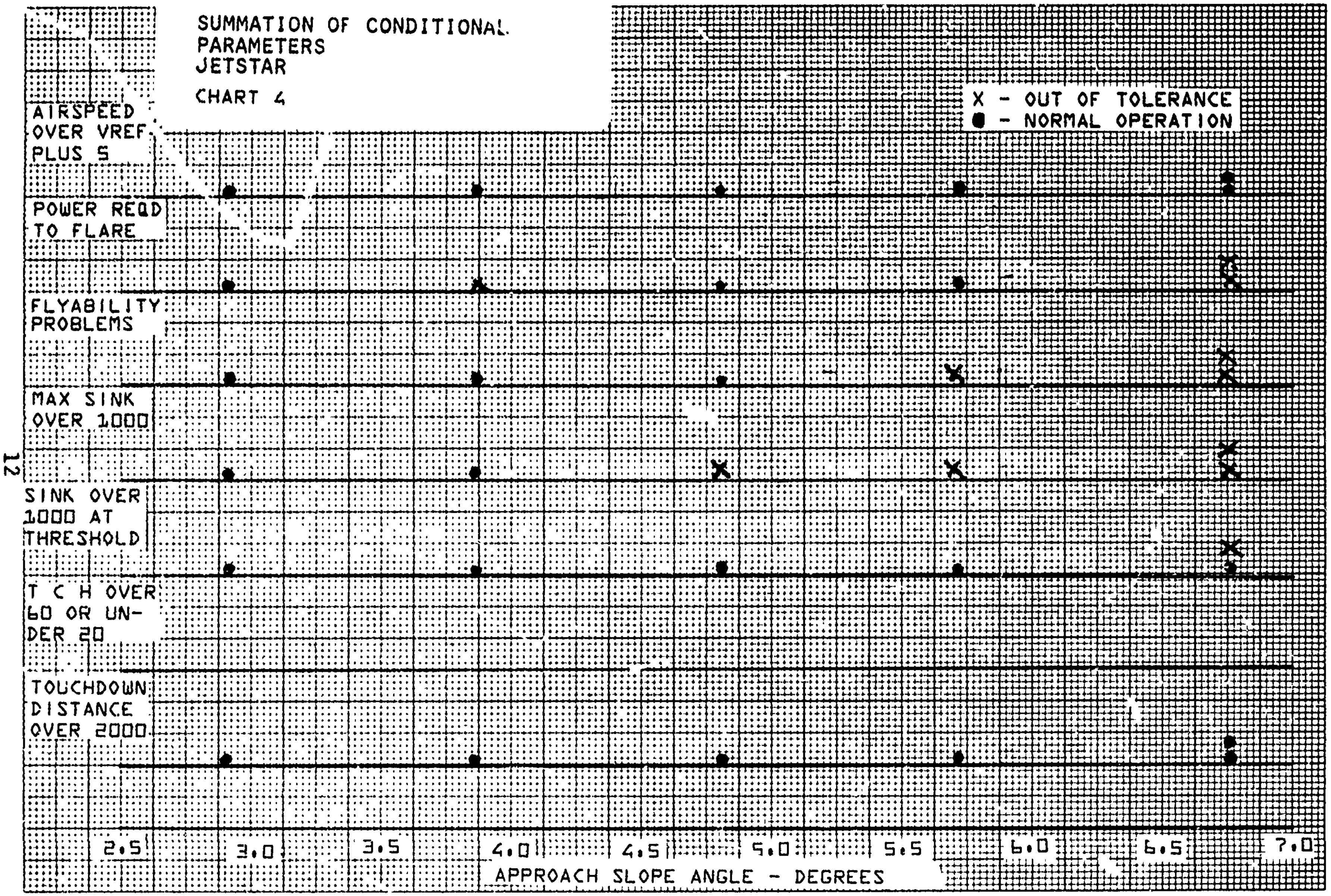
All Data. Chart 5, Page 13. Combined data. Some out of tolerance conditions begin showing themselves at 3.5 degrees, then at 4 degrees. Above 4 degrees, however, these conditions increase rapidly. Based upon the approaches flown in these test aircraft, it would appear that approach slopes in excess of 4 degrees can be expected to be accompanied by problems of flyability, power requirement in flare, high sink rates, and long touchdown distances.



SUMMATION OF CONDITIONAL
PARAMETERS
JET COMMANDER
CHART 1
X = OUT OF TOLERANCE
● = NORMAL OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


SUMMATION OF CONDITIONAL
PARAMETERS
LEAR JET
CHART 2
X = OUT OF TOLERANCE
● = NORMAL OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

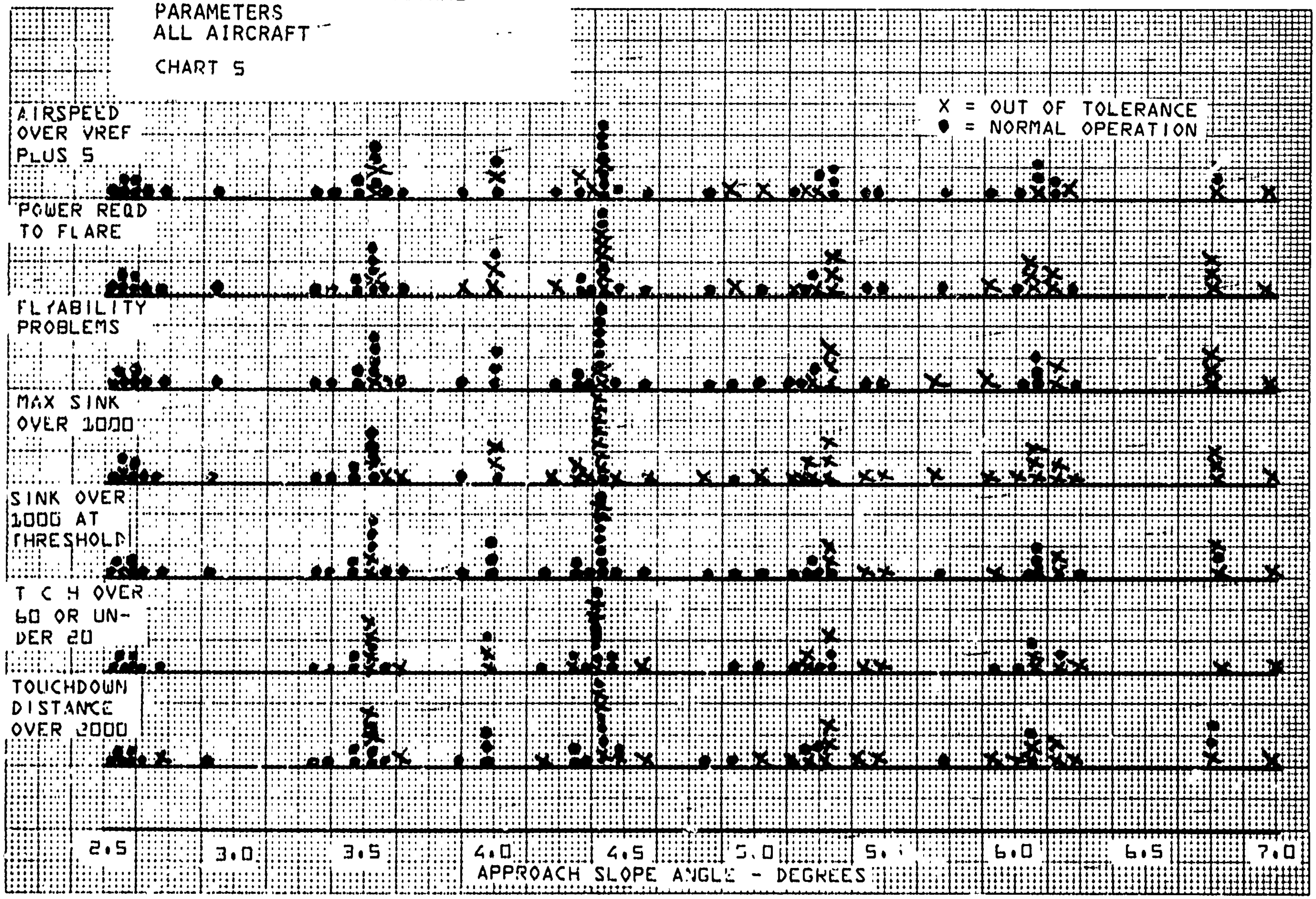

SUMMATION OF CONDITIONAL
PARAMETERS
SABRELINER
CHART 3
X - OUT OF TOLERANCE
● - NORMAL OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES



SUMMATION OF CONDITIONAL
PARAMETERS
JETSTAR
CHART 4
X - OUT OF TOLERANCE
- NORMAL OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

SUMMATION OF CONDITIONAL
PARAMETERS
ALL AIRCRAFT

CHART 5



FINDINGS

1. Some aircraft tested showed excursions outside tolerances at 3.5 degree approach angles. These excursions became frequent and general at angles above 4 degrees.

2. Specific effect on assigned tolerances were as follows:

   a. Airspeed during descent was affected directly only in the Sabreliner.

   b. At 4 degrees power application for the flare became a requirement.

   c. Problems in flyability began to manifest themselves at and over 4 degrees.

   d. Maximum sink rate and sink rate at the threshold increased out of tolerance at and over 4 degrees.

   e. Threshold crossing height appeared NOT to be affected by approach angle.

   f. Touchdown distances increase with increased approach slope, markedly so at and over 4 degrees.

3. Pilots accepted higher approach angles during day approaches than at night. Airspeed was more carefully held within tolerances at night. No other special differences between day and night operation was indicated.

4. Putting the aircraft in final approach configuration prior to reaching the one-mile point (Jet Commander and Lear Jet) provided a lower beginning airspeed at the start of descent resulting in more stable speed through the approach. This resulted in a better controlled and more comfortable approach for the pilot. In the Jet Commander an approach one degree higher was acceptable to the pilot using this technique.

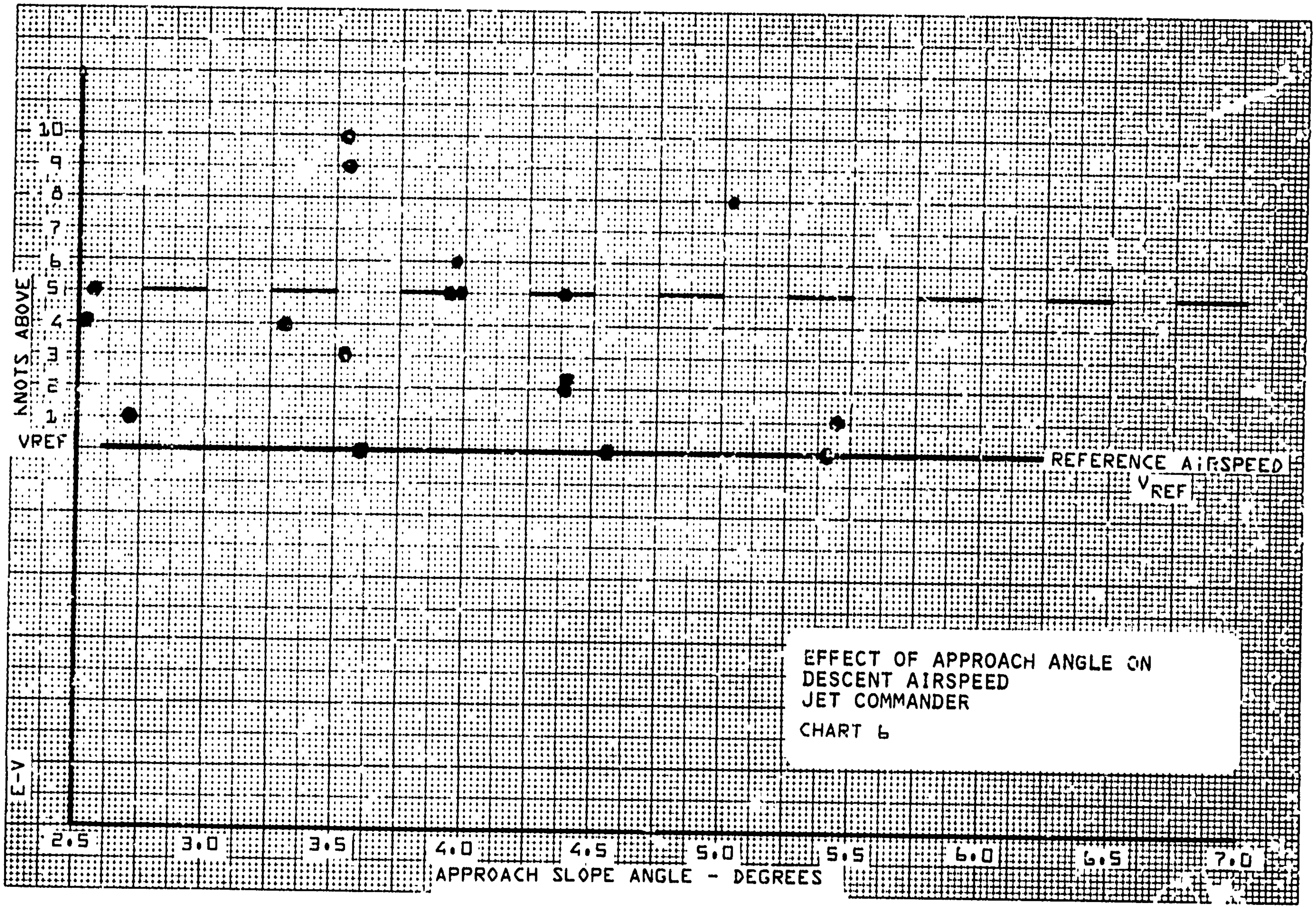
5. Altimetry system lag causes indicated altitude to be higher than actual height at the threshold on final approach.

APPENDIX

A-1 & 2	Data Tabulation
A-3 - 7	Effect of Approach Angle on Descent Airspeed
A-8 - 12	Effect of Approach Angle on Power Required in Flare
A-13 - 17	Effect of Approach Angle on Flyability
A-18 - 22	Effect of Approach Slope on Max Sink Rate
A-23 - 27	Effect of Approach Slope on Threshold Sink Rate
A-28 - 31	Effect of Approach Slope on T C H
A-32 - 36	Effect of Approach Slope on Touchdown Distance
A-37 - 40	Comparison of Night vs Day Approaches
A-41 - 44	Comparison of Indicated vs Actual altitude at TH.
A-45	Conversion of Approach Slope Angle to Descent Gradient.

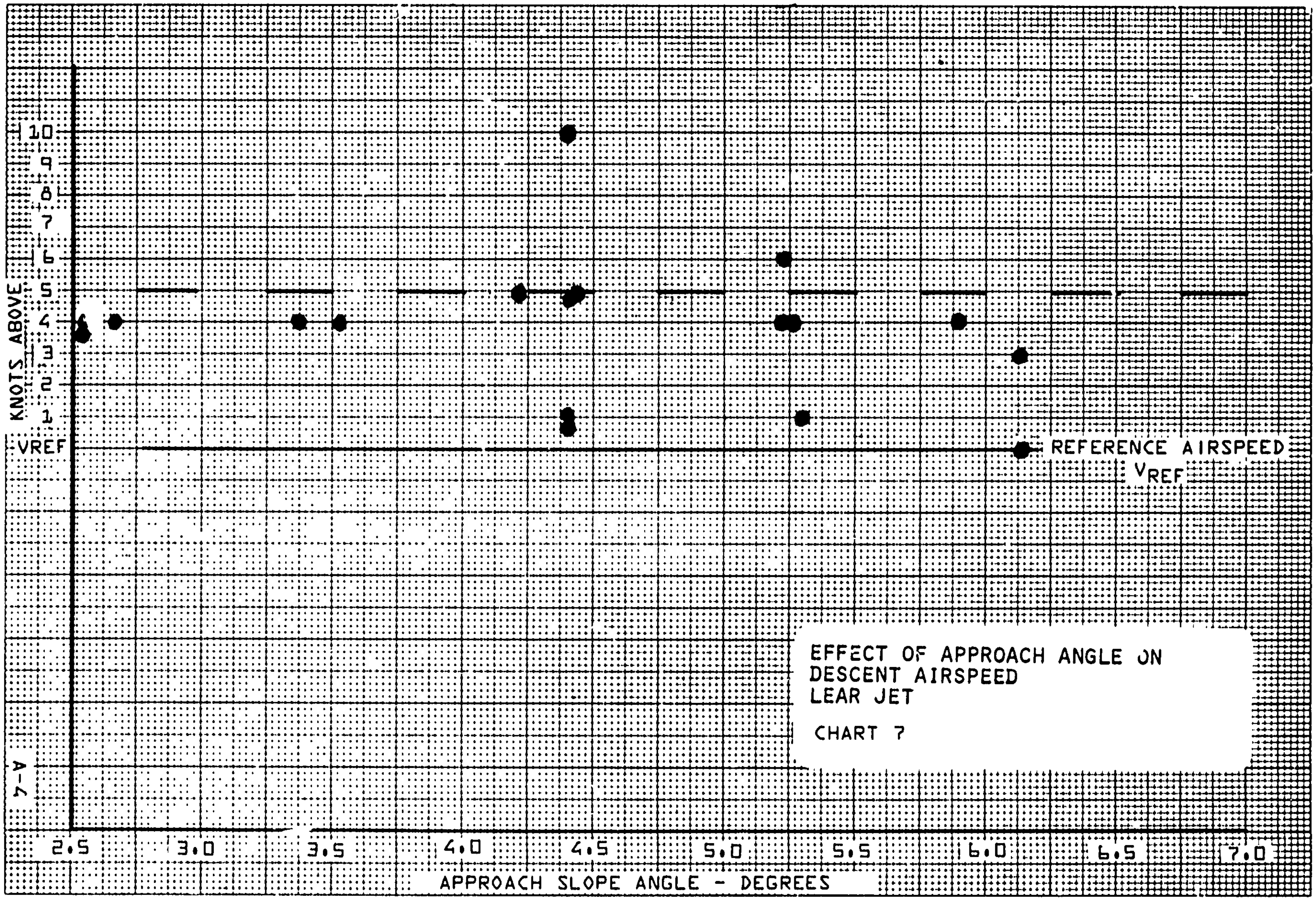
RUN	APPROACH ANGLE	CONDITION	ACFT TYPE	AIR SPEED	REF SPEED	POWER REQ'D	DIFFICULT APPROACH	MAX SINK	THRESH SINK	TCH	TD DIST	REMARKS
1	2.52	Day	JC	125	121					22	1250	
2	3.30	Day	JC	125	121					[illegible]	1320	
3	3.98	Day	JC	125	120	YES				19	720	
4	5.03	Day	JC	125	118	YES				22	920	
5	2.56	Day	JC	125	120			1120	600	28	1000	
6	3.54	Day	JC	130	120		YES	1600	1100	98	2000	
7	4.40	Day	JC	120	118	YES	YES	1100	1000	Missed Approach		
8	4.40	Day	JC	120	116	YES	YES	1600	900	49	2800	
9	3.97	Day	JC	120	114	YES		1700	800	71	1800	
10	3.53	Day	JC	115	112	YES		1600	1100	[illegible]	2000	Early set
11	3.55	Day	JC	120	111			900	800	53	2400	"
12	4.40	Day	JC	115	110			1500	900	46	1800	"
13	3.90	Day	JC	115	110			1500	500	53	2000	"
14	2.71	Night	JC	120	121			500	500	47	2300	"
15	3.[illegible]2	Night	JC	120	120			1200	600	77	2400	"
16	Missed approach											
17	4.56	Night	JC	116	116			1500	900	66	2500	"
18	5.47	Night	JC	115	114			1500	1100	90	3000	"
19	5.42	Night	JC	112	112			1500	1100	71	2500	"
20	2.54	Day	LJ	135	131			600	500	27	1700	
21	3.37	Day	LJ	135	131			800	500	28	1500	
22	4.22	Day	LJ	135	130	YES		1100	500	25	2250	
23	5.23	Day	LJ	135	129	YES	YES	1200	800	63	2700	OK VFR
24	6.14	Day	LJ	128	128	YES	YES	1500	1100	97	3200	OK VFR
25	5.89	Day	LJ	130	125	YES	YES	1400	1100	20	2900	Early set
26	6.13	Day	LJ	128	125	YES	YES	1500	1200	50	3400	"
27	4.39	Day	LJ	135	125			1000	800	44	2800	"
28	2.66	Night	LJ	135	131			600	400	22	1050	"
29	3.54	Night	LJ	135	131			1000	500	41	1450	"
30	4.43	Night	LJ	135	130			1200	800	36	1525	"
31	[illegible].41	Night	LJ	130	129	YES		1700	1000	31	1700	"
32	5.30	Night	LJ	130	129	YES	YES	1300	1000	58	2000	"
33	5.26	Night	LJ	130	126	YES	YES	2000	1100	63	2500	"
34	5.30	Night	LJ	130	126	YES	YES	1500	1300	58	2400	"

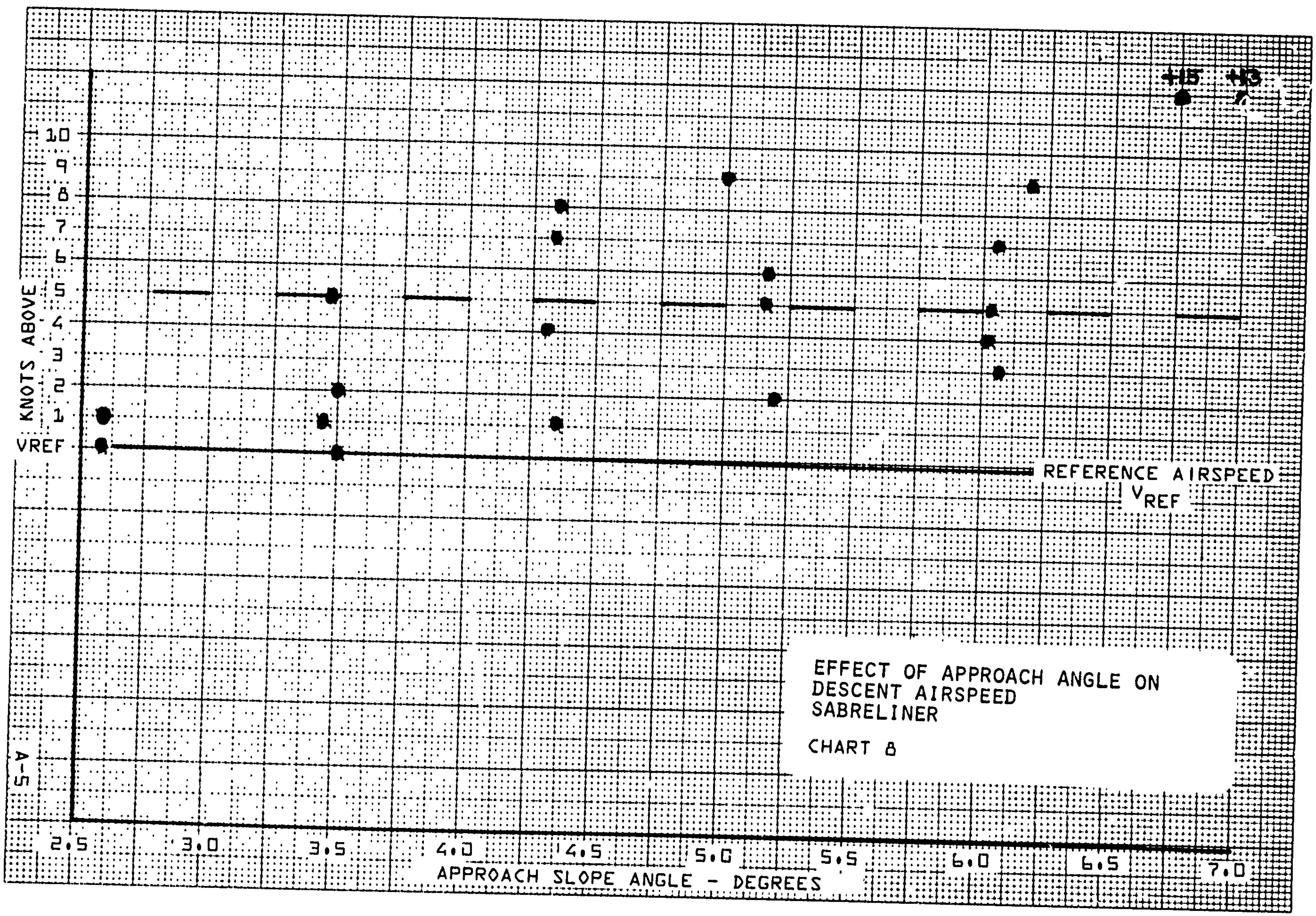
35	4.42	Night	LJ	130	125	YES		2000	1400	64	2350	Early set
36	4.41	Night	LJ	125	124	YES		1300	1100	66	2000	"
37	2.58	Day	SL	125	125			500	400	33	1050	
38	3.50	Day	SL	125	125			800	600	16	1330	
39	4.31	Day	SL	128	124			1700	800	17	1500	
40	5.17	Day	SL	130	124			1500	700	13	1720	
41	6.06	Day	SL	140	123	YES		1600	1100	19	2400	
42	6.97	Day	SL	135	122	YES	YES	2200	1100	33	2200	Exceptional techniques
43	4.35	Day	SL	130	122			1100	1000	25	1500	
44	4.99	Day	SL	130	121			1800	800	35	2800	
45	6.13	Day	SL	130	121			1600	700	19	2250	
46	5.76	Day	SL	135	120	YES	YES	1800	1300	16	2250	Same
47	6.02	Day	SL	125	120			1800	1000	35	2350	
48	2.58	Night	SL	125	124			600	400		1800	
49	3.50	Night	SL	125	123			800	500	74	2750	
50	4.37	Night	SL	124	123			1200	700	43	1900	
51	5.21	Night	SL	124	122			1600	700	52	2000	
52	6.07	Night	SL	124	121	YES		2000	800	70	2400	
53	3.47	Night	SL	122	121			900	500	40	1950	
54	3.47	Night	SL	124	119			800	400	25	1950	
55	4.34	Night	SL	125	118			1300	500	25	1550	
56	5.16	Night	SL	122	117	YES		1500	800	48	2600	
57	6.06	Night	SL	120	116	YES		1800	800	40	1550	
58	2.87	Day	JS	138	137			500	300		1150	
59	3.85	Day	JS	136	136	YES		800	300		1280	
60	4.80	Day	JS	134	134			1900	300		1100	Max IFR
61	5.72	Day	JS	130	131		YES	1800	300		1050	VFR Only
62	6.76	Day	JS	130	131	YES	YES	2100	400		1850	
63	6.76	Day	JS	130	130	YES	YES	1900	1500		1200	DME, then flare

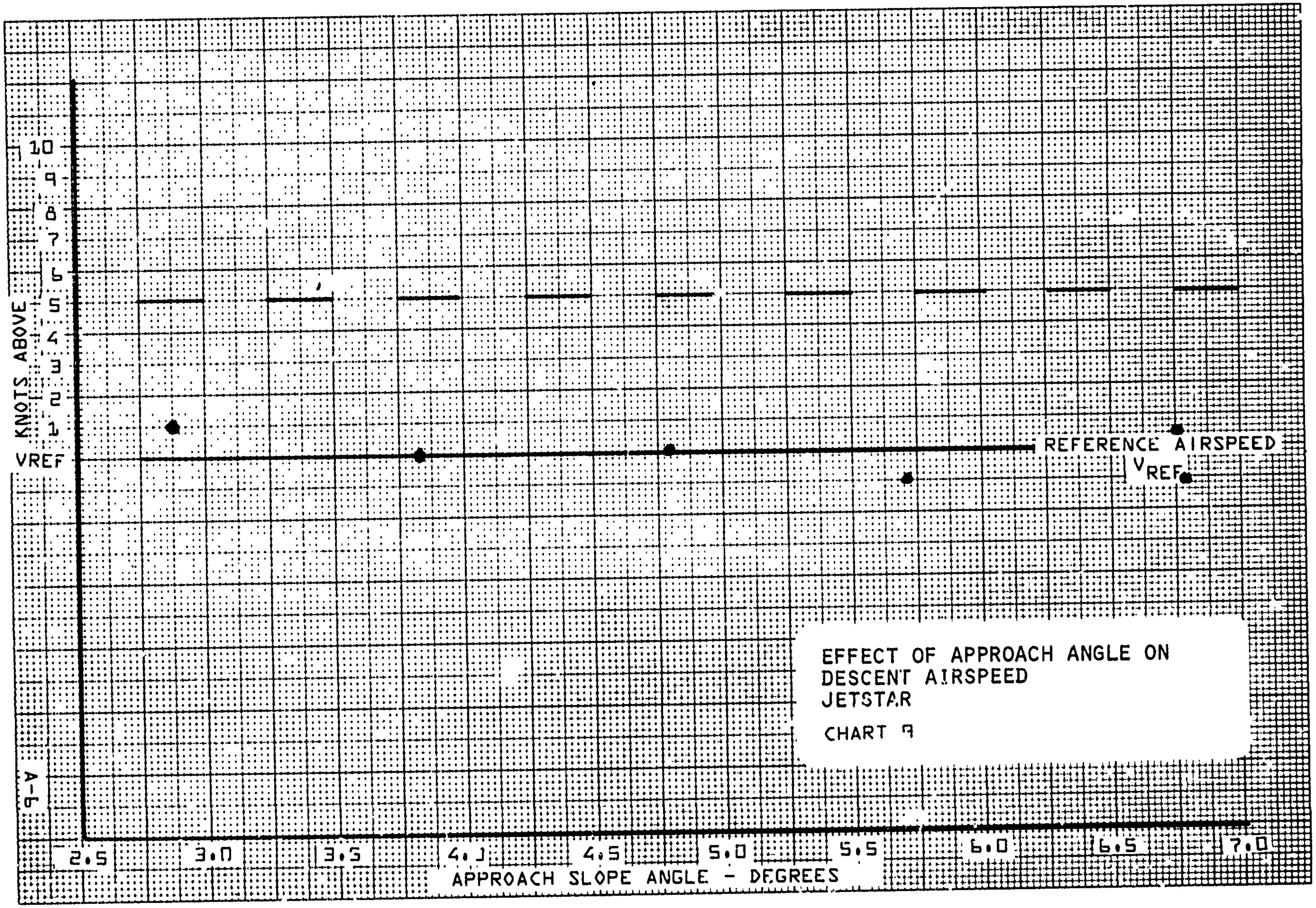


EFFECT OF APPROACH ANGLE ON DESCENT AIRSPEED
JET COMMANDER

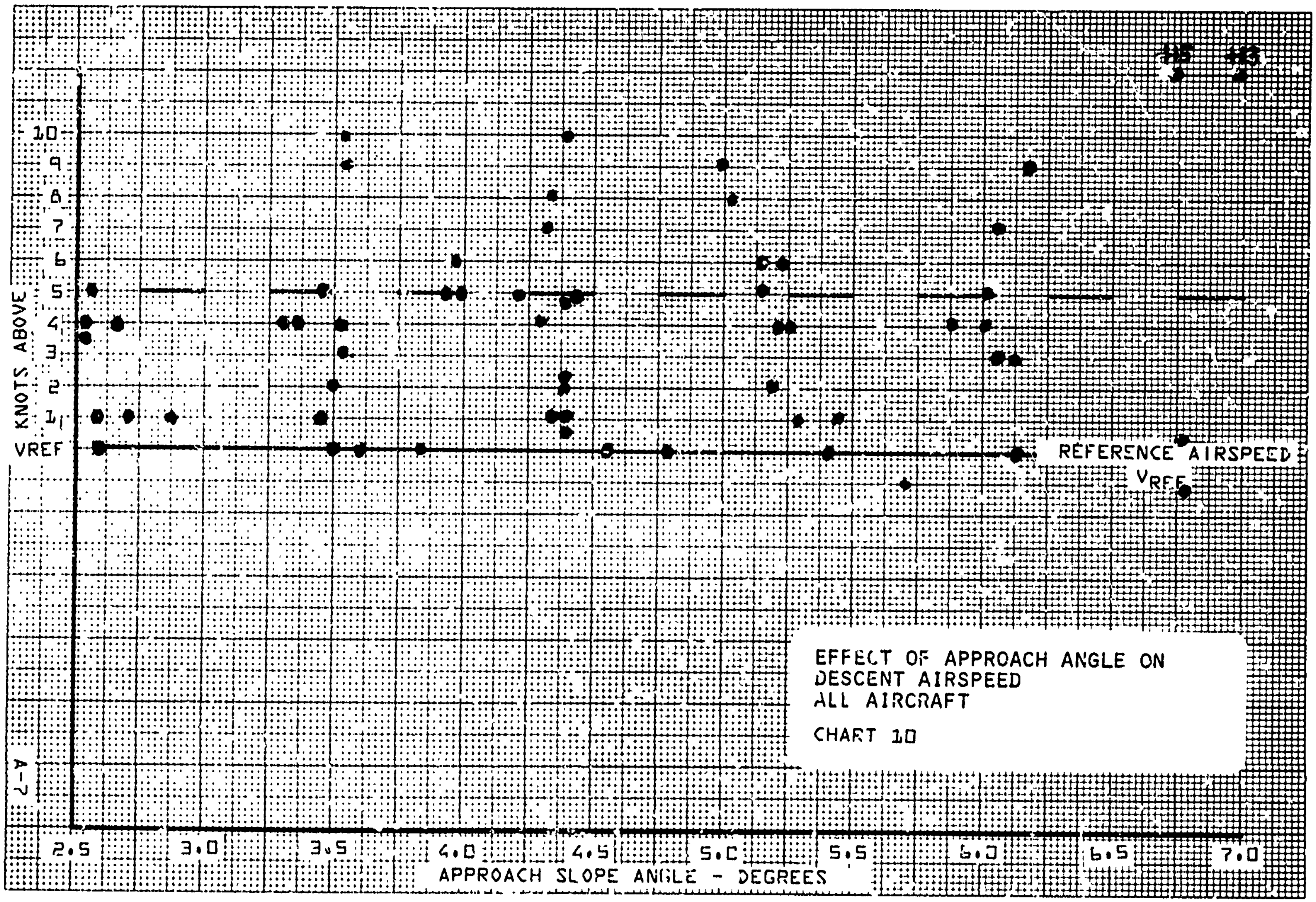
CHART 6


EFFECT OF APPROACH ANGLE ON
DESCENT AIRSPEED
LEAR JET
CHART 7
KNOTS ABOVE
10
9
8
7
6
5
4
3
2
1
VREF
REFERENCE AIRSPEED
V_{REF}
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


+15
+13
10
9
8
7
6
5
4
3
2
1
VREF
KNOTS ABOVE
REFERENCE AIRSPEED
V_{REF}
EFFECT OF APPROACH ANGLE ON
DESCENT AIRSPEED
SABRELINER
CHART 8
A-5
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

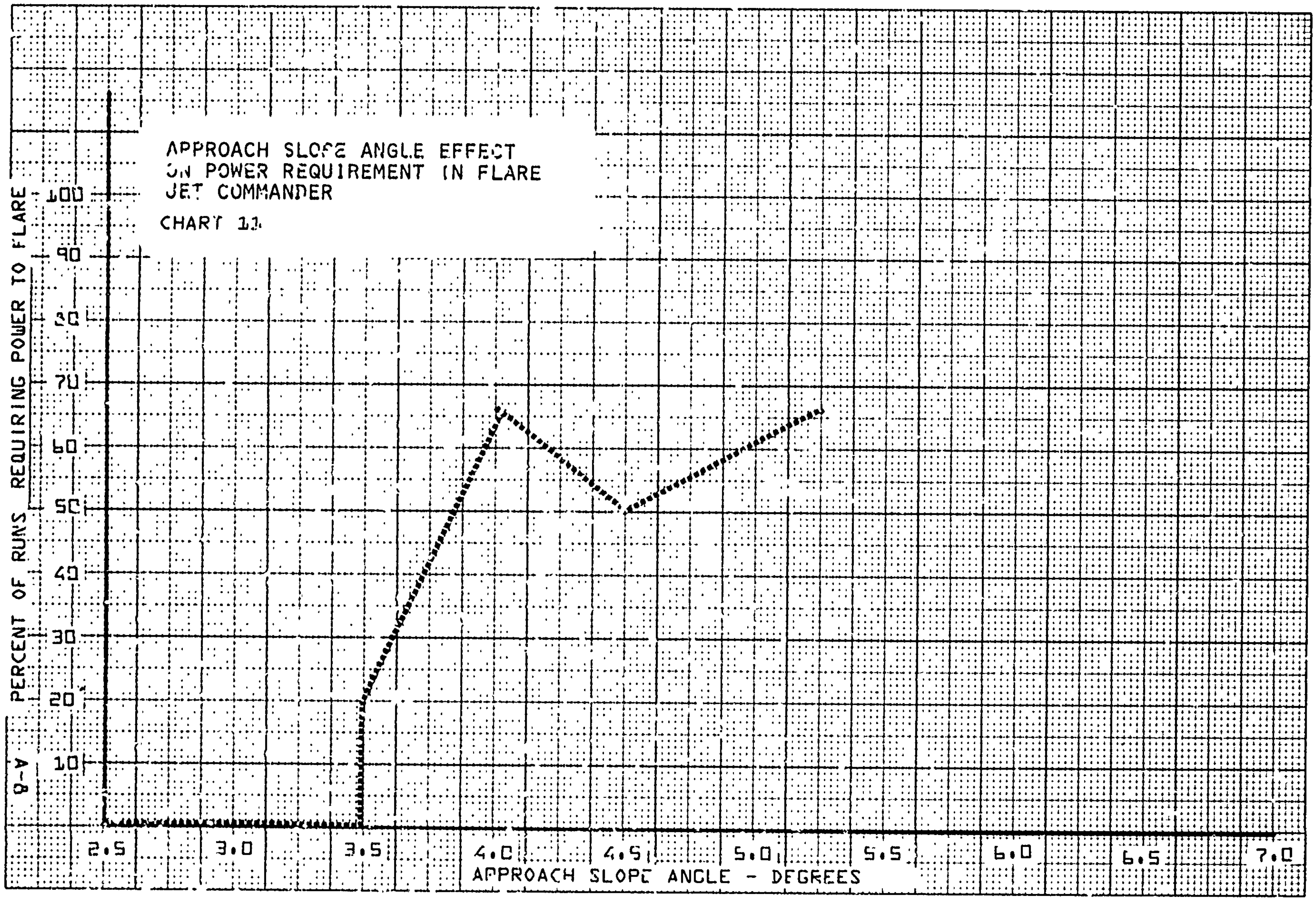


KNOTS ABOVE VREF
10
9
8
7
6
5
4
3
2
1
REFERENCE AIRSPEED V_{REF}
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES
EFFECT OF APPROACH ANGLE ON
DESCENT AIRSPEED
JETSTAR
CHART 9



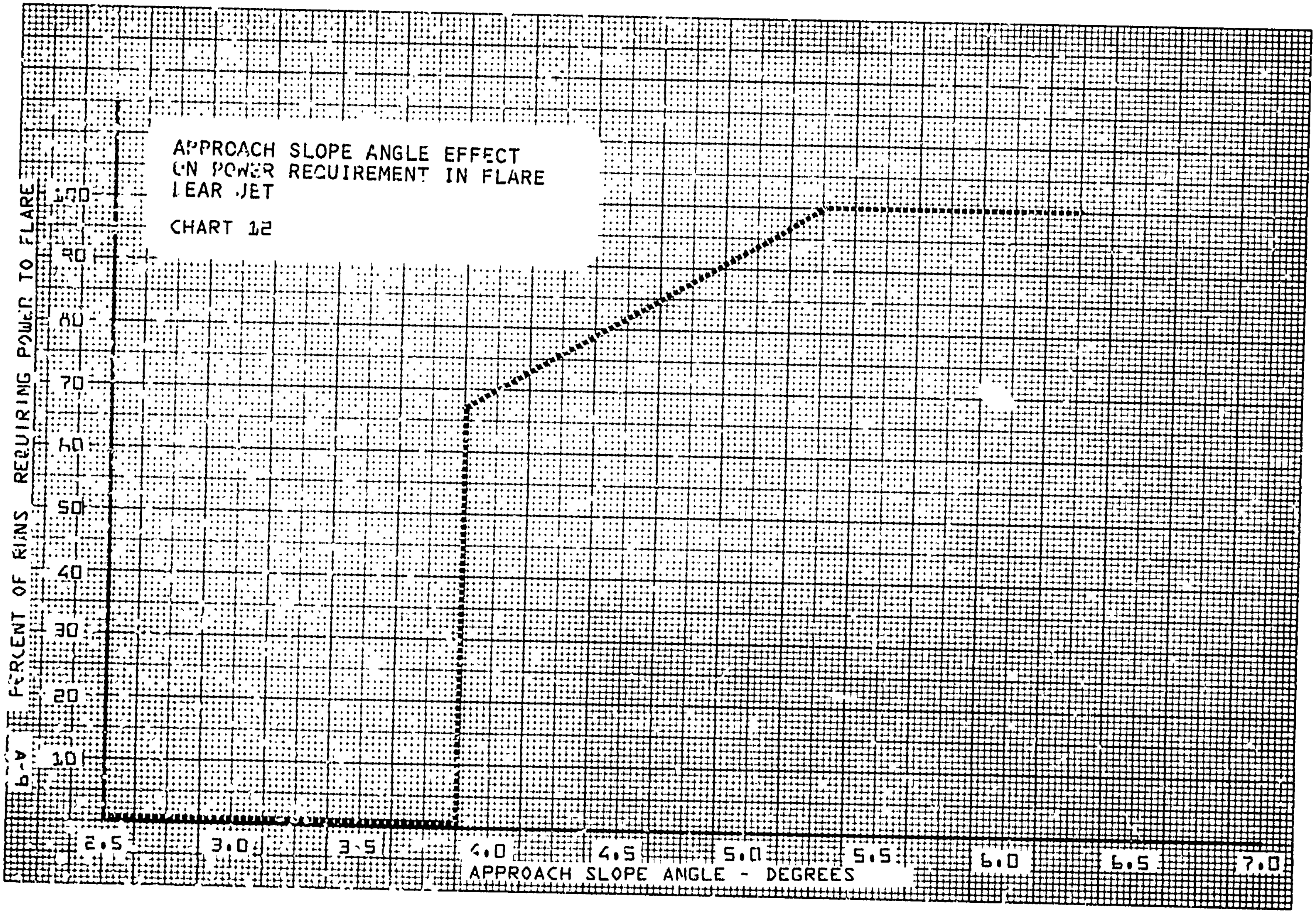
EFFECT OF APPROACH ANGLE ON
DESCENT AIRSPEED
ALL AIRCRAFT

CHART 10



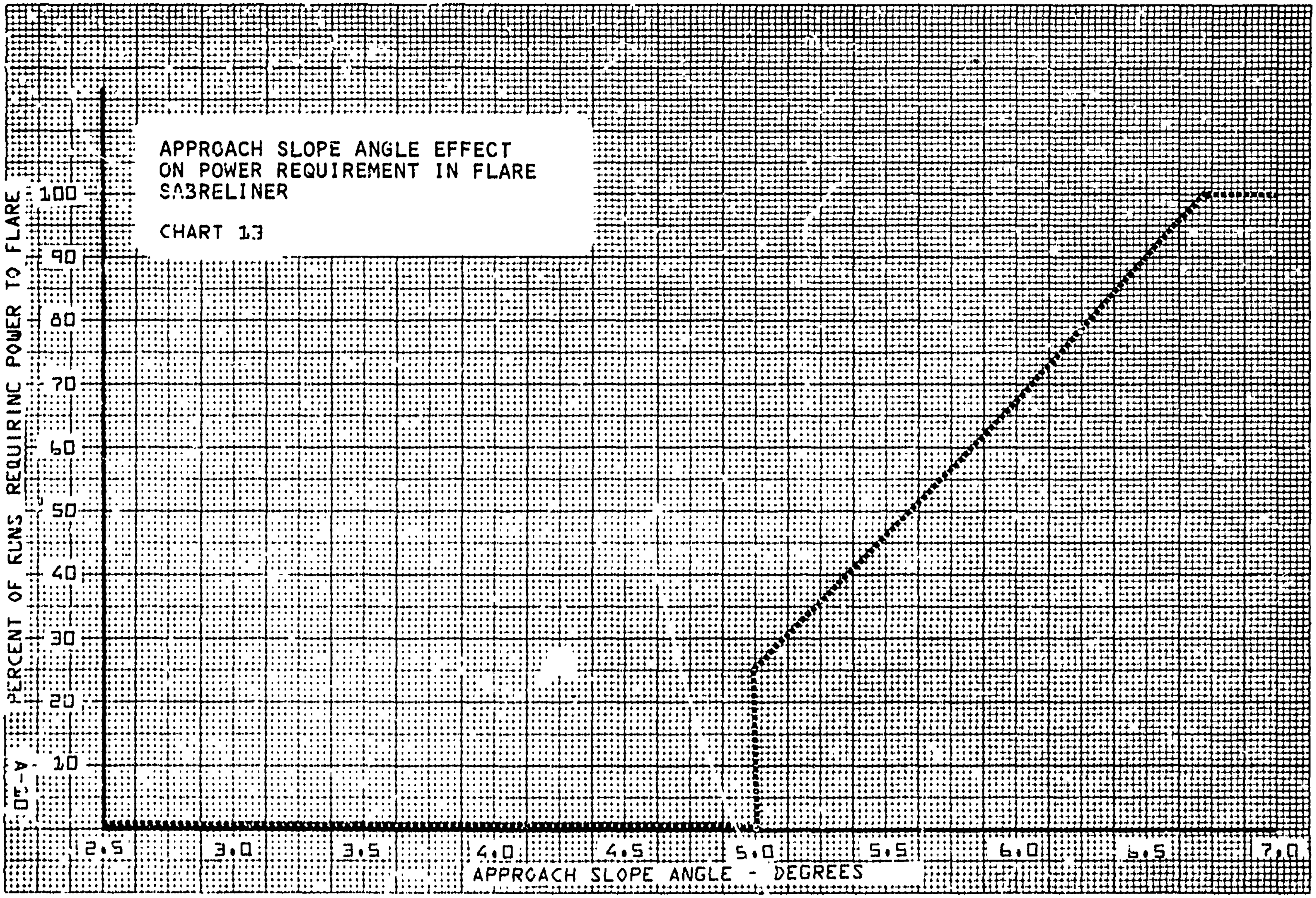
APPROACH SLOPE ANGLE EFFECT
ON POWER REQUIREMENT IN FLARE
JET COMMANDER

CHART 11



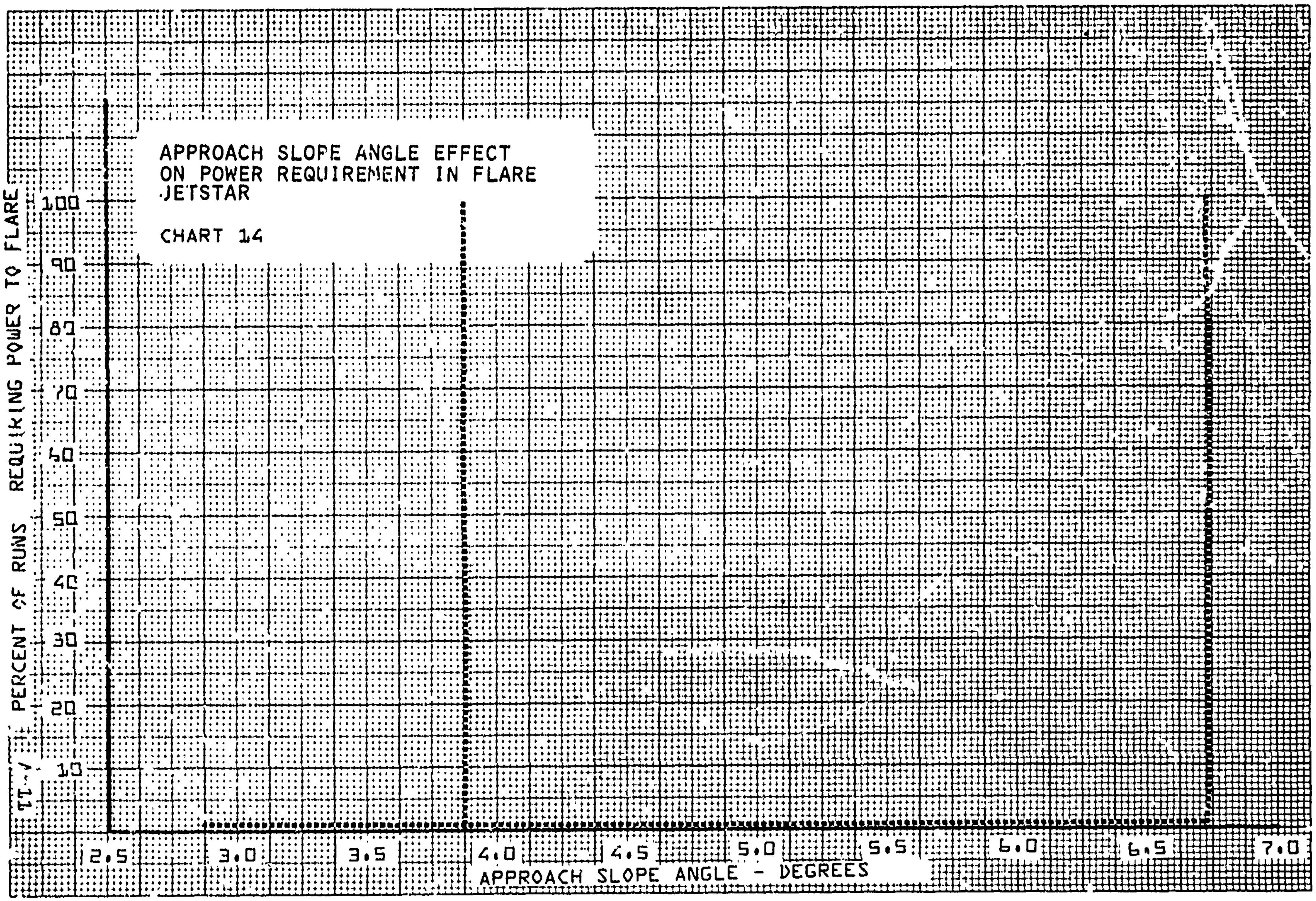
APPROACH SLOPE ANGLE EFFECT
ON POWER REQUIREMENT IN FLARE
LEAR JET
CHART 12
PERCENT OF RUNS REQUIRING POWER TO FLARE
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

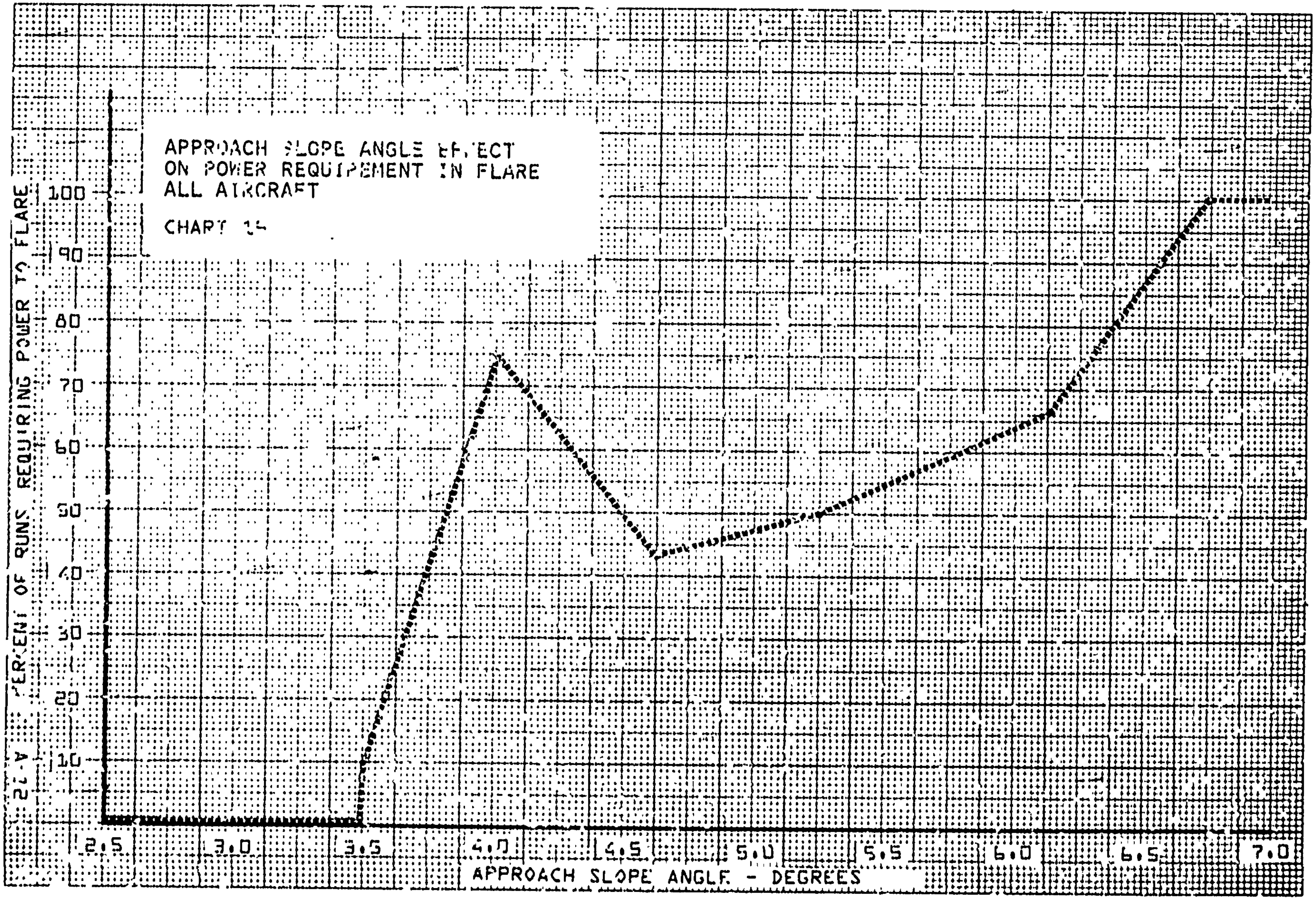
A-9

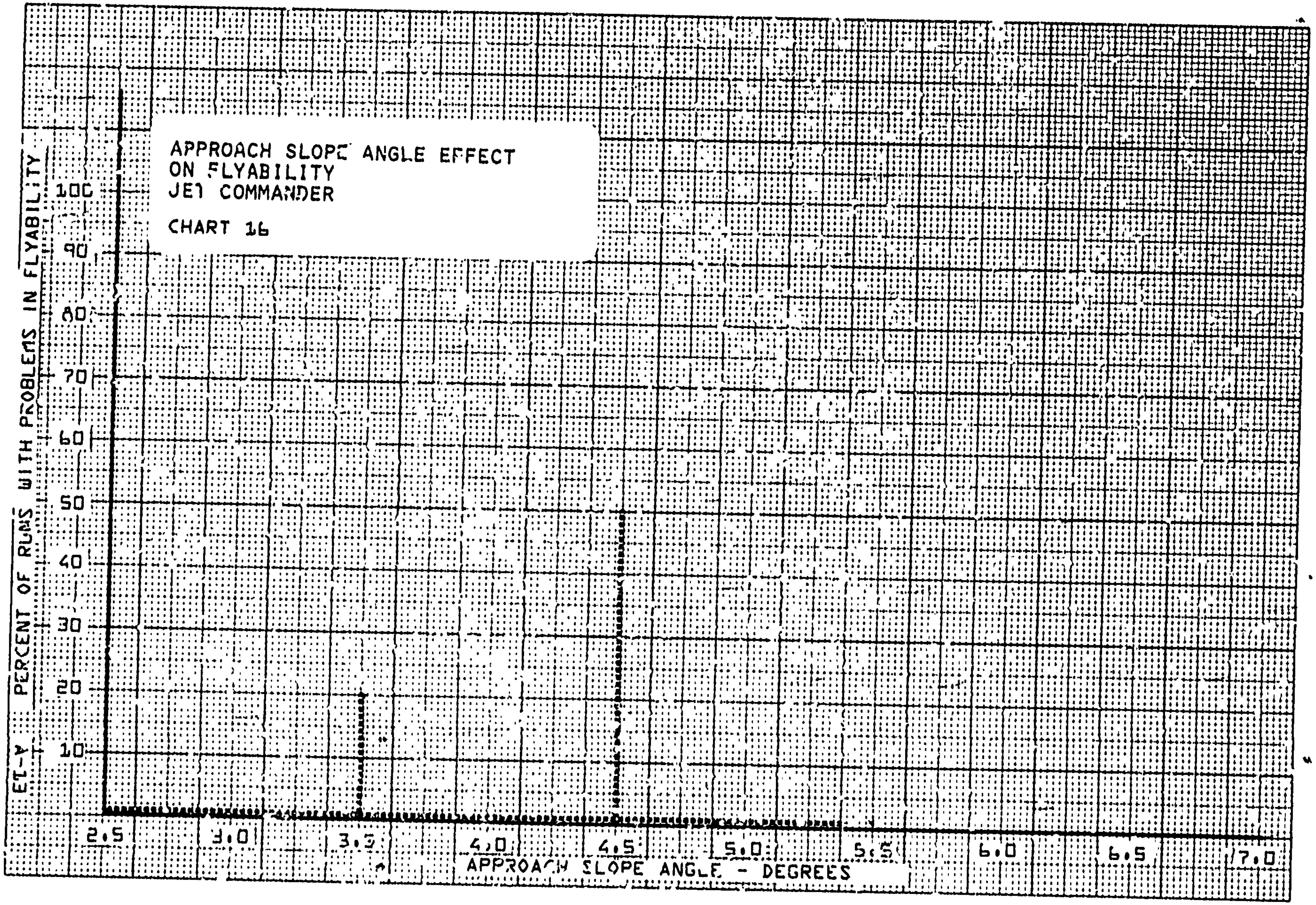


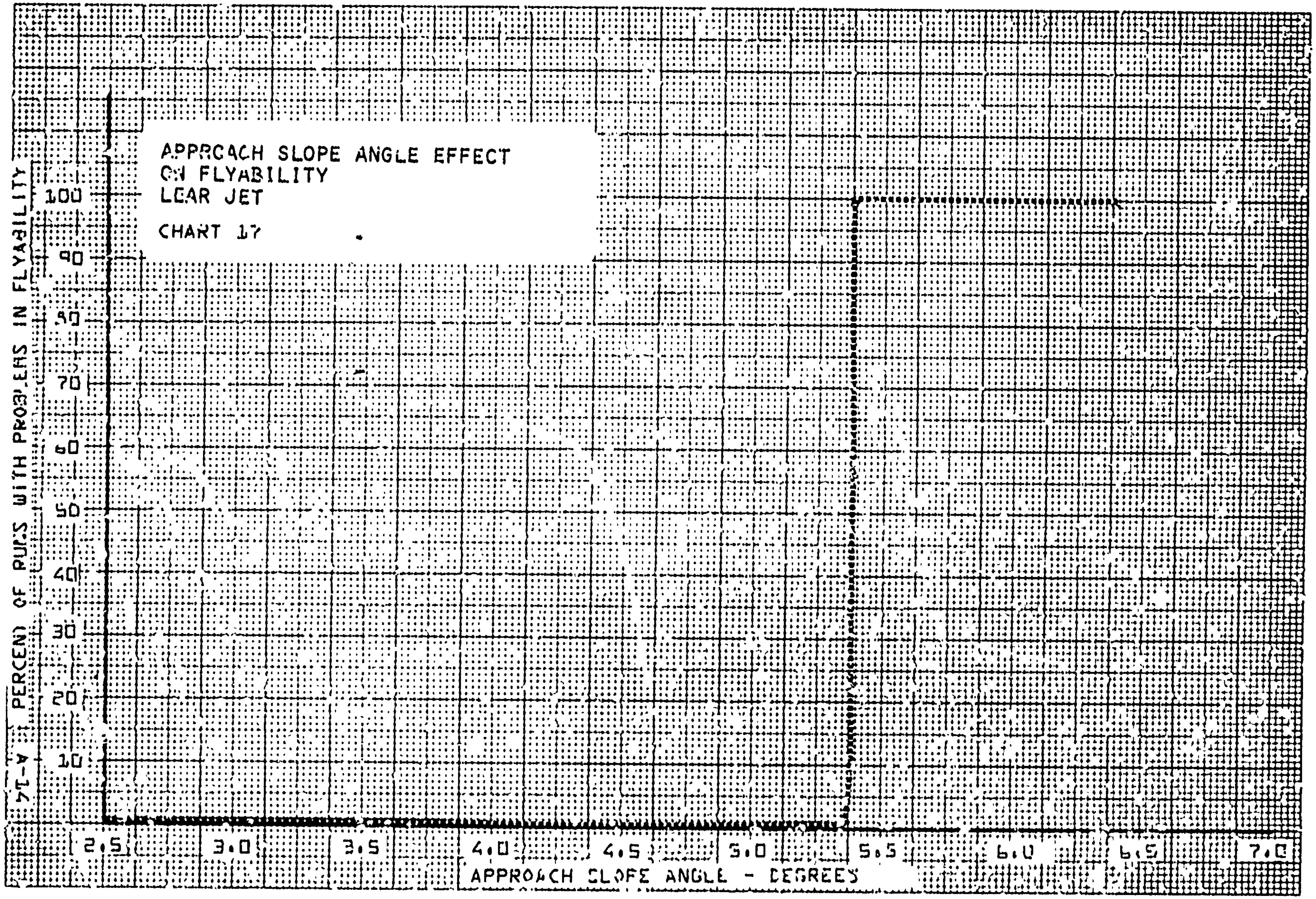
APPROACH SLOPE ANGLE EFFECT
ON POWER REQUIREMENT IN FLARE
SABRELINER
CHART 13
PERCENT OF RUNS REQUIRING POWER TO FLARE
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

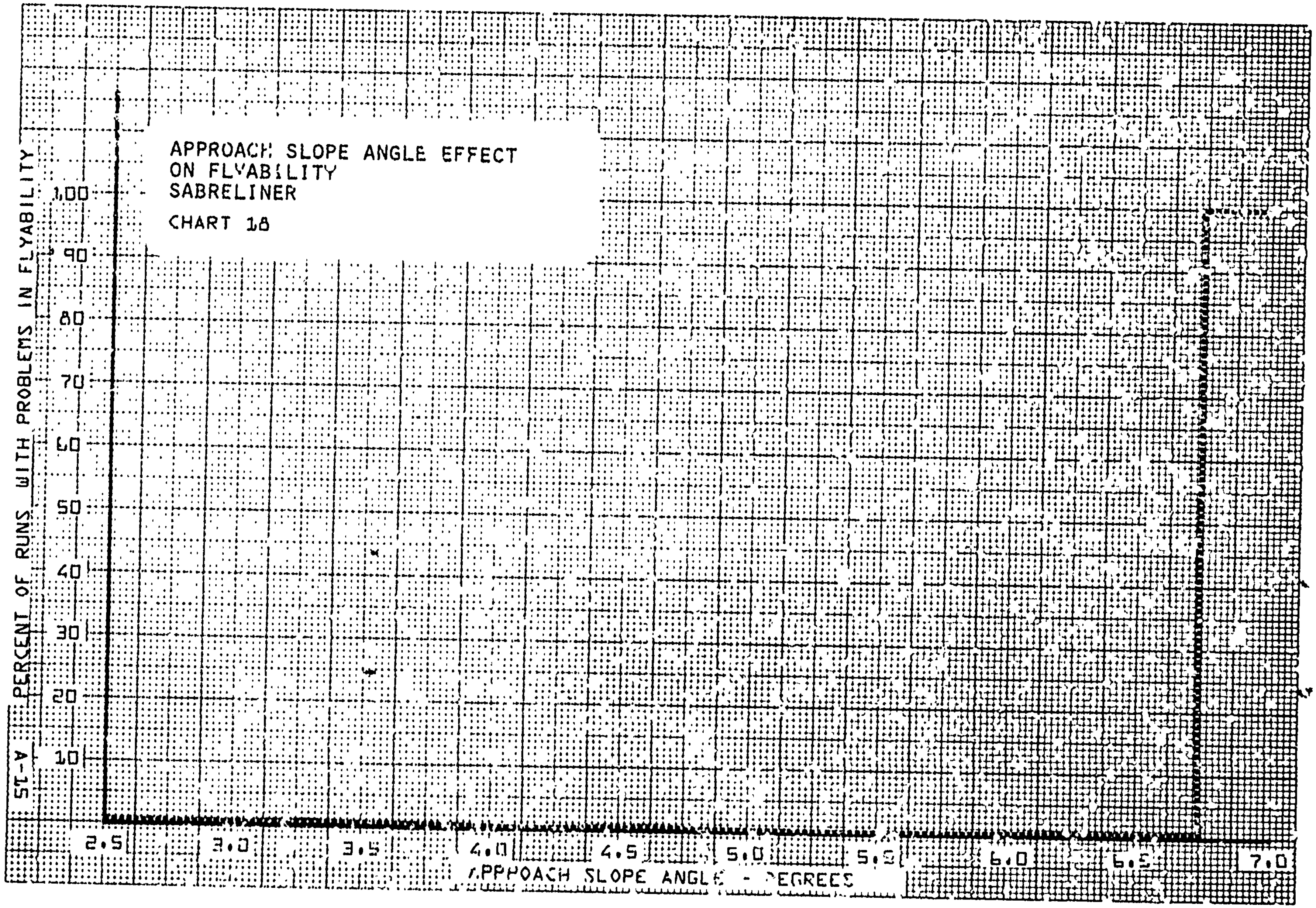
A-10

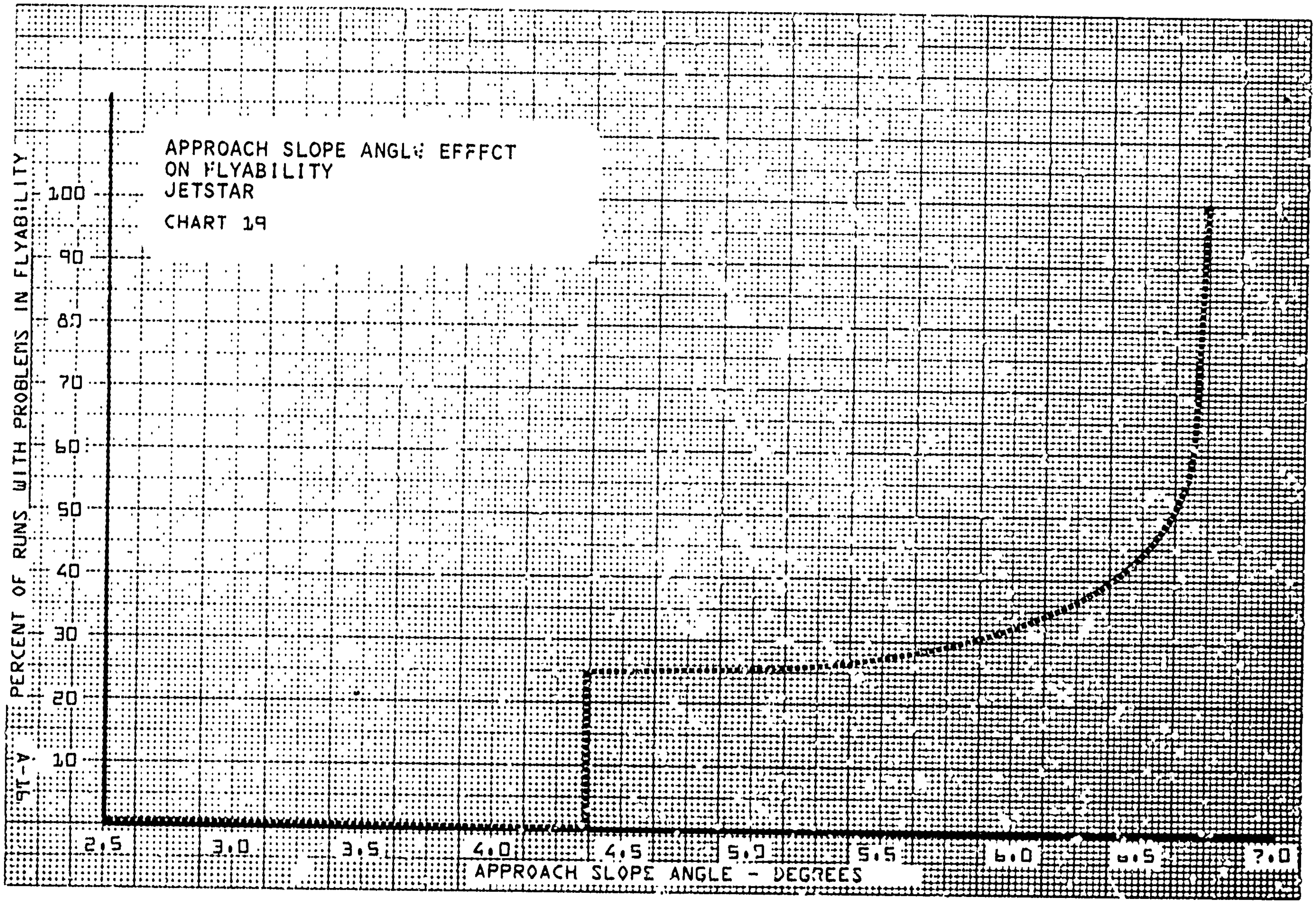

APPROACH SLOPE ANGLE EFFECT
ON POWER REQUIREMENT IN FLARE
JETSTAR
CHART 14
PERCENT OF RUNS REQUIRING POWER TO FLARE
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

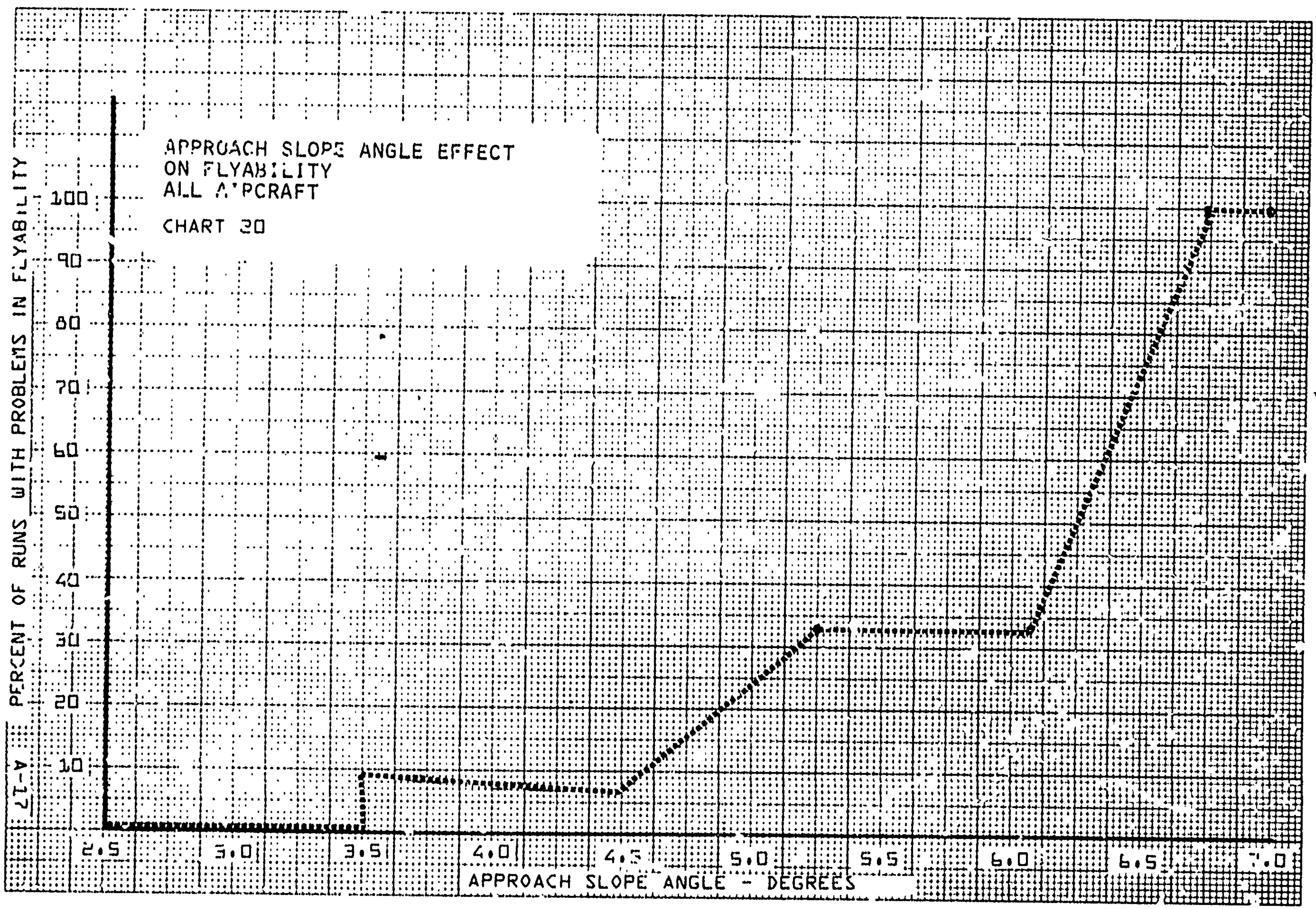

APPROACH SLOPE ANGLE EFFECT
ON POWER REQUIREMENT IN FLARE
ALL AIRCRAFT
CHART 15
PERCENT OF RUNS REQUIRING POWER TO FLARE
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

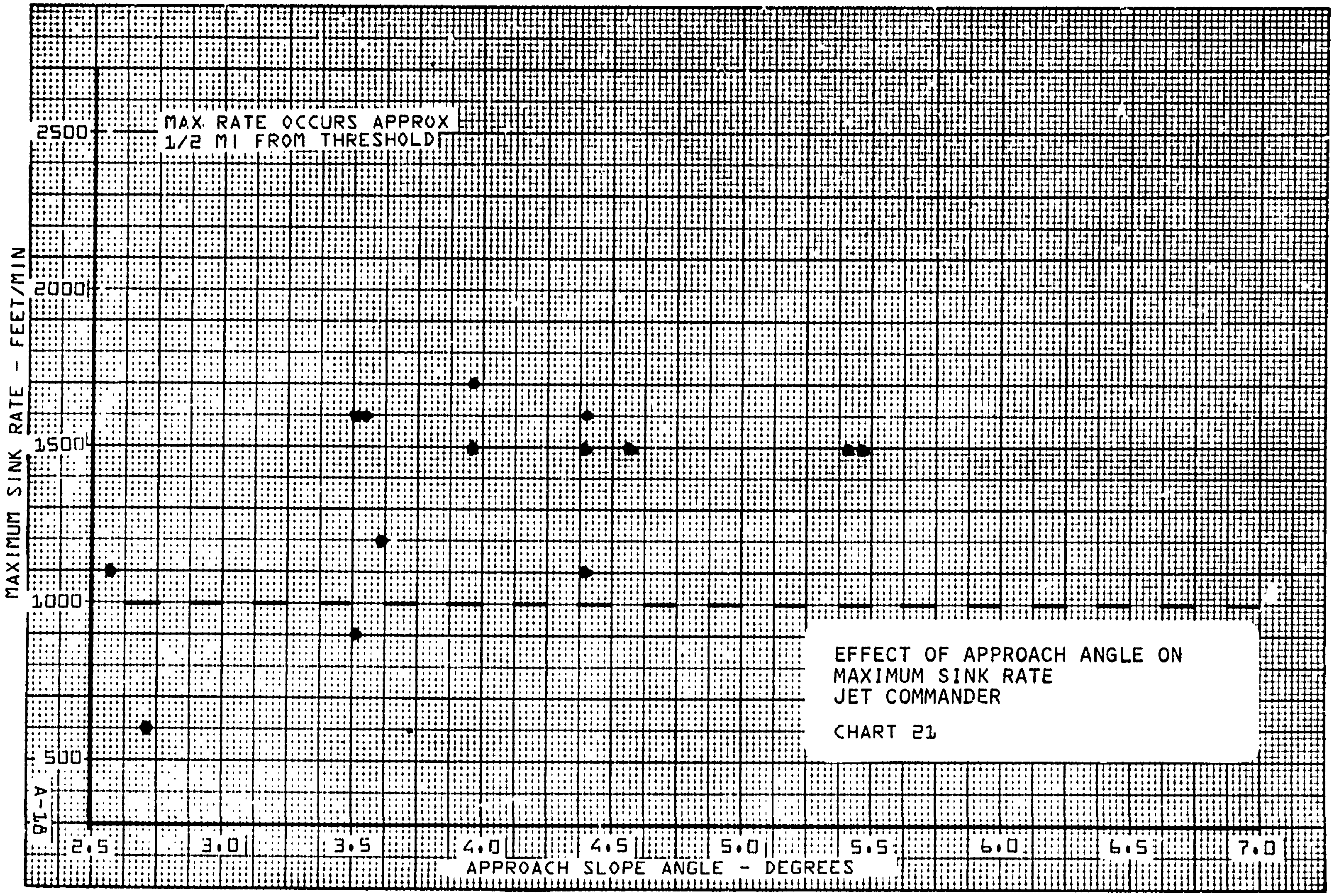

APPROACH SLOPE ANGLE EFFECT
ON FLYABILITY
JET COMMANDER
CHART 16
ET-V PERCENT OF RUNS WITH PROBLEMS IN FLYABILITY
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


APPROACH SLOPE ANGLE EFFECT
ON FLYABILITY
LEAR JET
CHART 17
PERCENT OF RUNS WITH PROBLEMS IN FLYABILITY
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES
A-14


APPROACH SLOPE ANGLE EFFECT
ON FLYABILITY
SABRELINER
CHART 18
PERCENT OF RUNS WITH PROBLEMS IN FLYABILITY
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

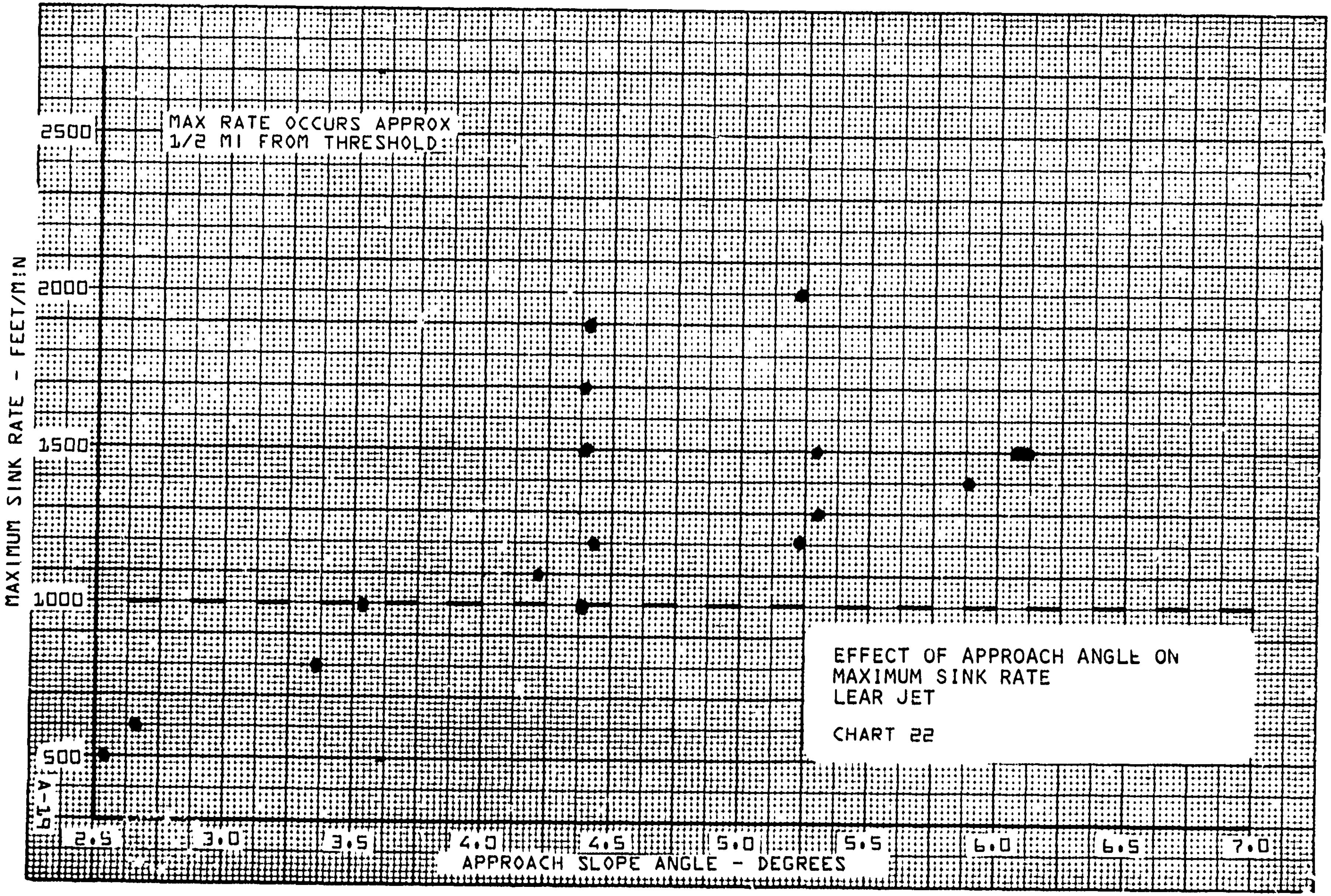

APPROACH SLOPE ANGLE EFFECT
ON FLYABILITY
JETSTAR
CHART 19
PERCENT OF RUNS WITH PROBLEMS IN FLYABILITY
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


APPROACH SLOPE ANGLE EFFECT
ON FLYABILITY
ALL AIRCRAFT
CHART 20
PERCENT OF RUNS WITH PROBLEMS IN FLYABILITY
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES



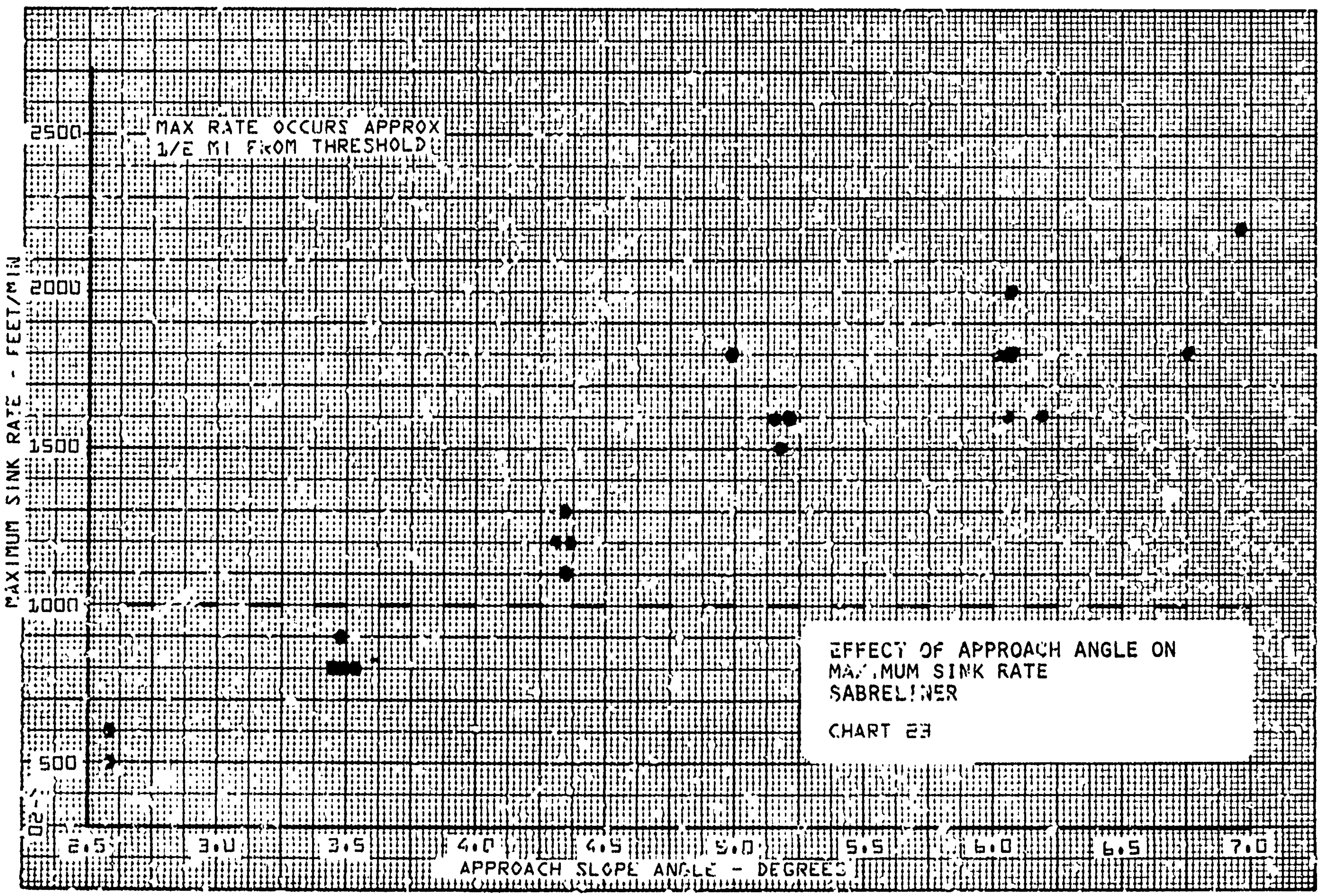
EFFECT OF APPROACH ANGLE ON
MAXIMUM SINK RATE
JET COMMANDER

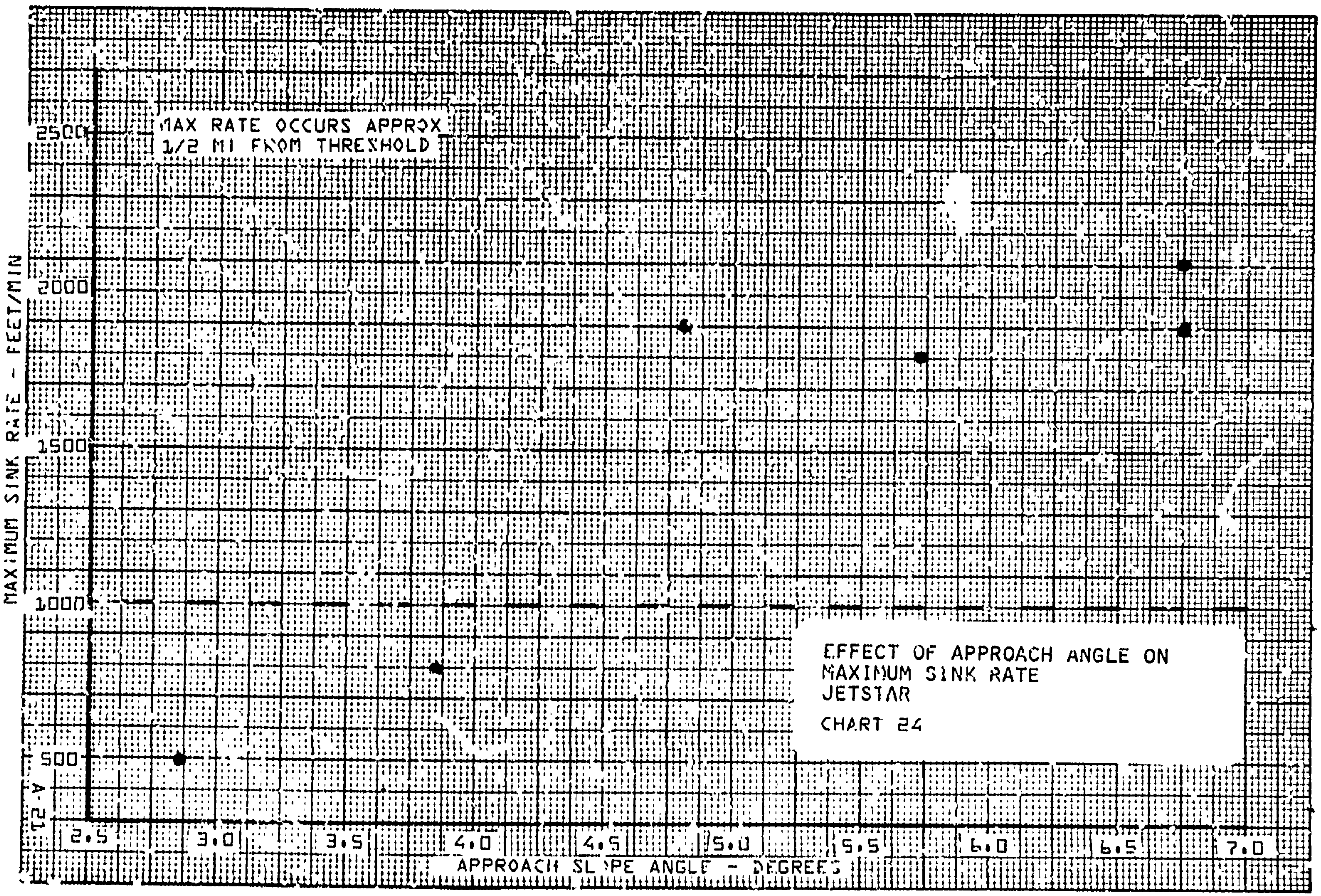
CHART 21

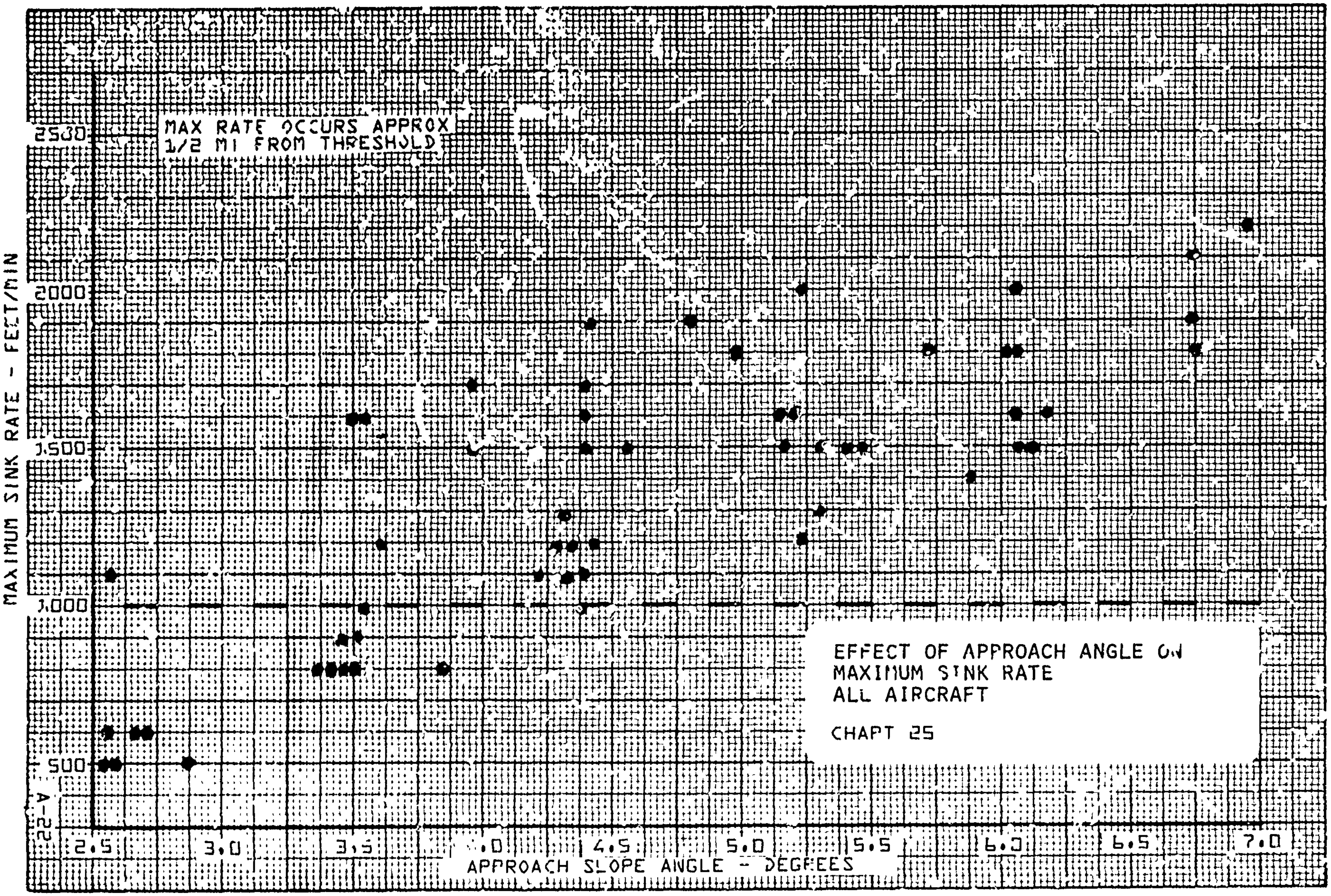


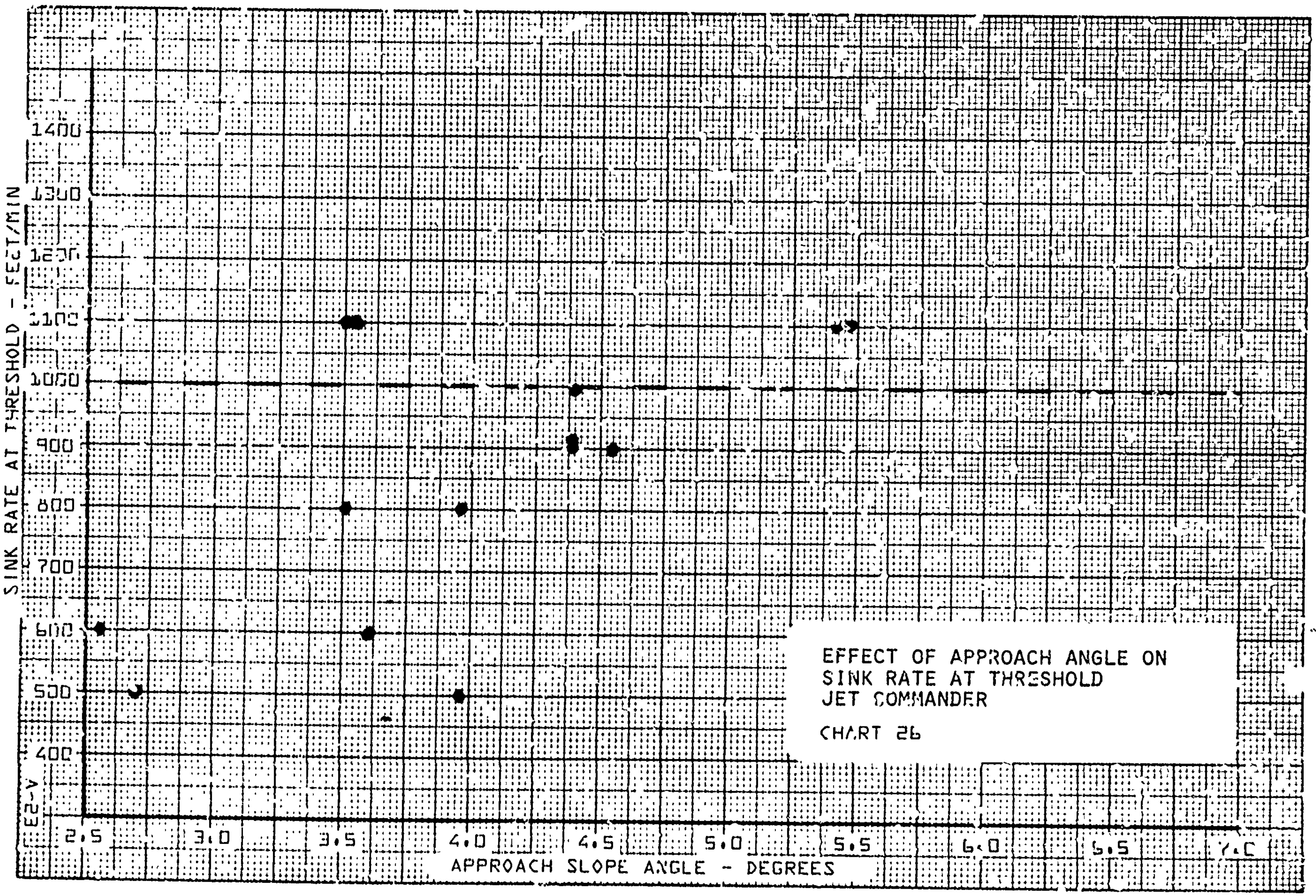
EFFECT OF APPROACH ANGLE ON
MAXIMUM SINK RATE
LEAR JET

CHART 22


MAX RATE OCCURS APPROX
1/2 MI FROM THRESHOLD
2500
2000
1500
1000
500
MAXIMUM SINK RATE - FEET/MIN
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES
EFFECT OF APPROACH ANGLE ON
MAXIMUM SINK RATE
SABRELINER
CHART 23

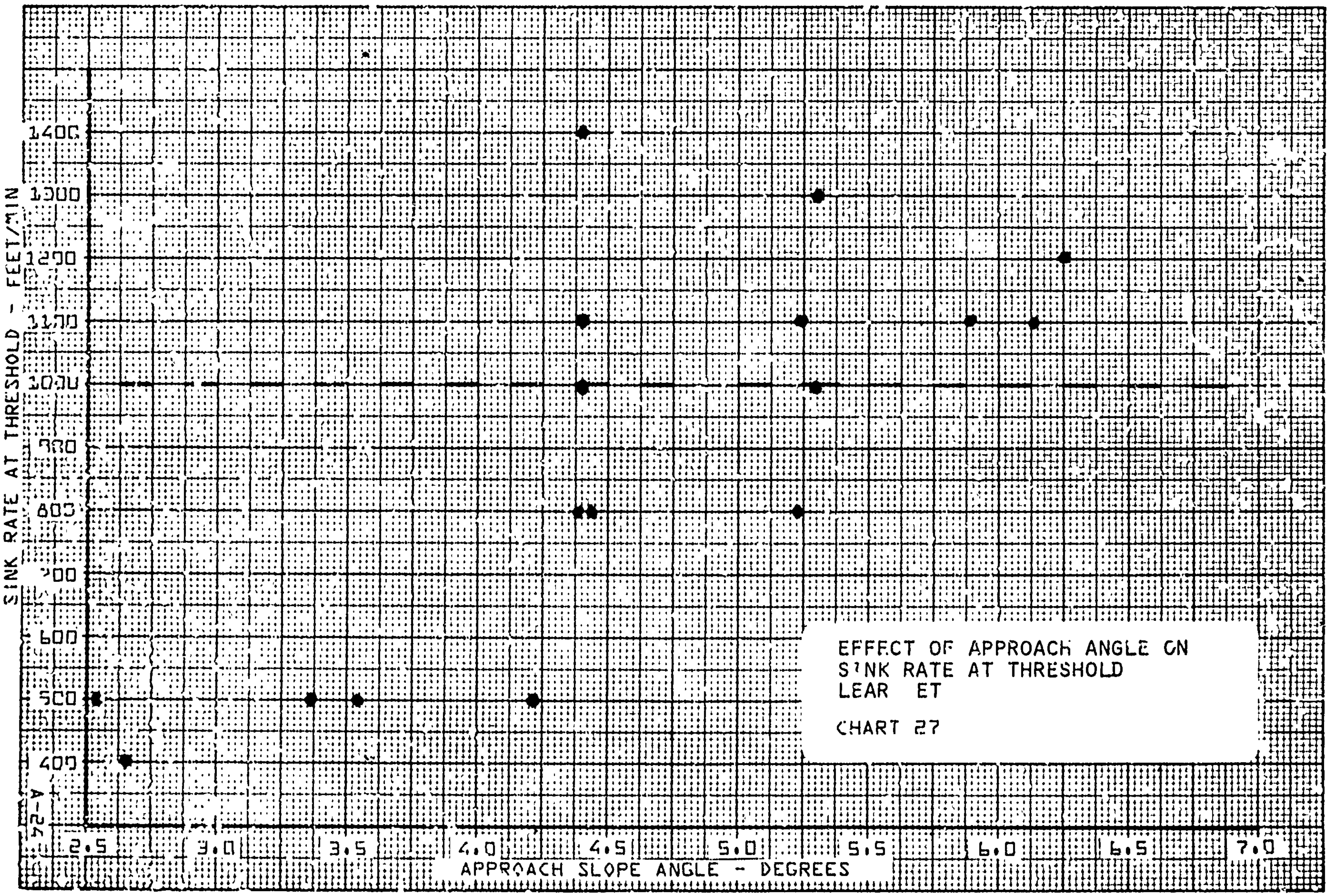

MAX RATE OCCURS APPROX
1/2 MI FROM THRESHOLD
2500
2000
1500
1000
500
MAXIMUM SINK RATE - FEET/MIN
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES
EFFECT OF APPROACH ANGLE ON
MAXIMUM SINK RATE
JETSTAR
CHART 24

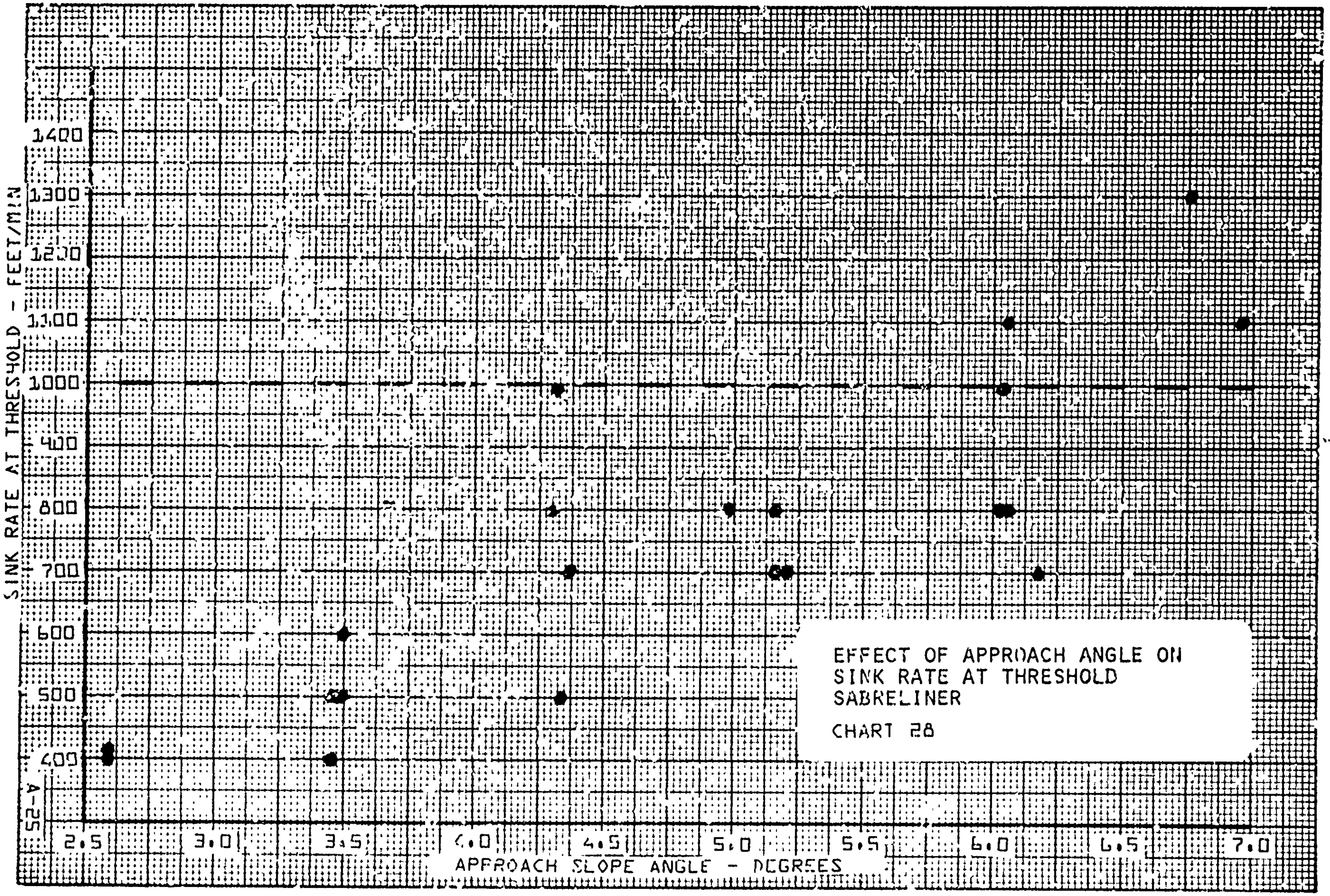

MAX RATE OCCURS APPROX
1/2 MI FROM THRESHOLD
MAXIMUM SINK RATE - FEET/MIN
2500
2000
1,500
1,000
500
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES
EFFECT OF APPROACH ANGLE ON
MAXIMUM SINK RATE
ALL AIRCRAFT
CHAPT 25



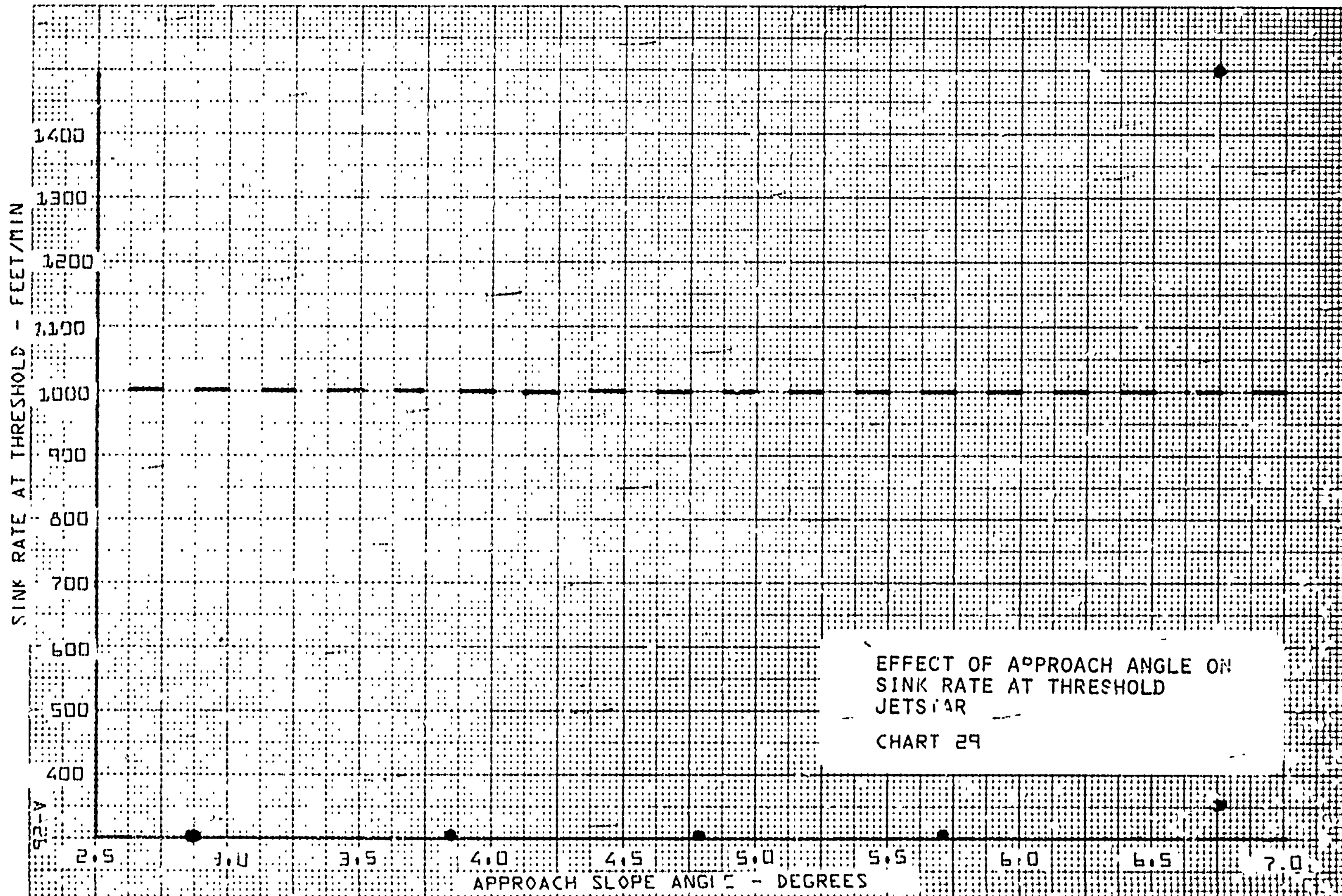
EFFECT OF APPROACH ANGLE ON
SINK RATE AT THRESHOLD
JET COMMANDER

CHART 26


EFFECT OF APPROACH ANGLE ON
SINK RATE AT THRESHOLD
LEAR ET
CHART 27
SINK RATE AT THRESHOLD - FEET/MIN
1400
1300
1200
1100
1000
900
800
700
600
500
400
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

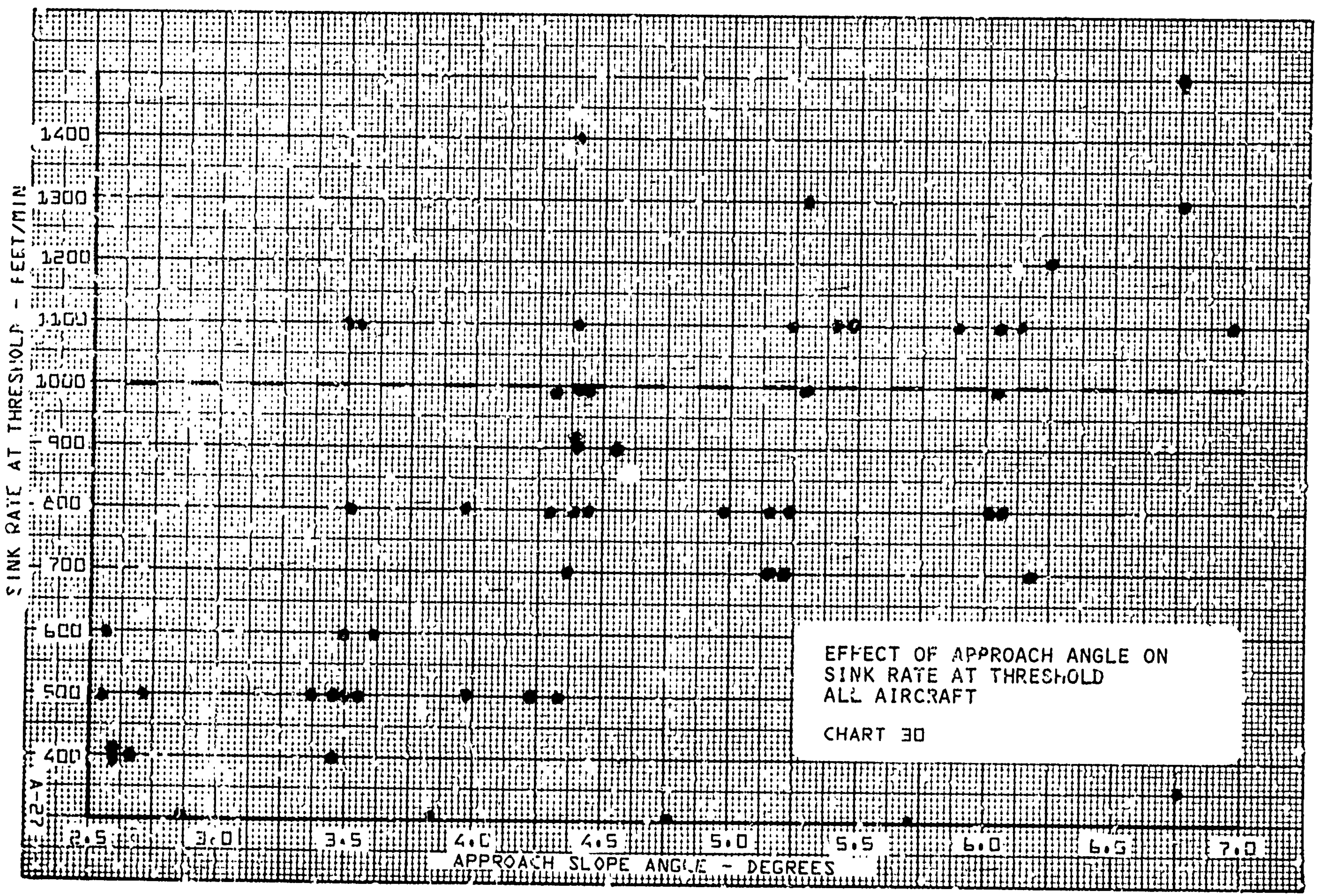


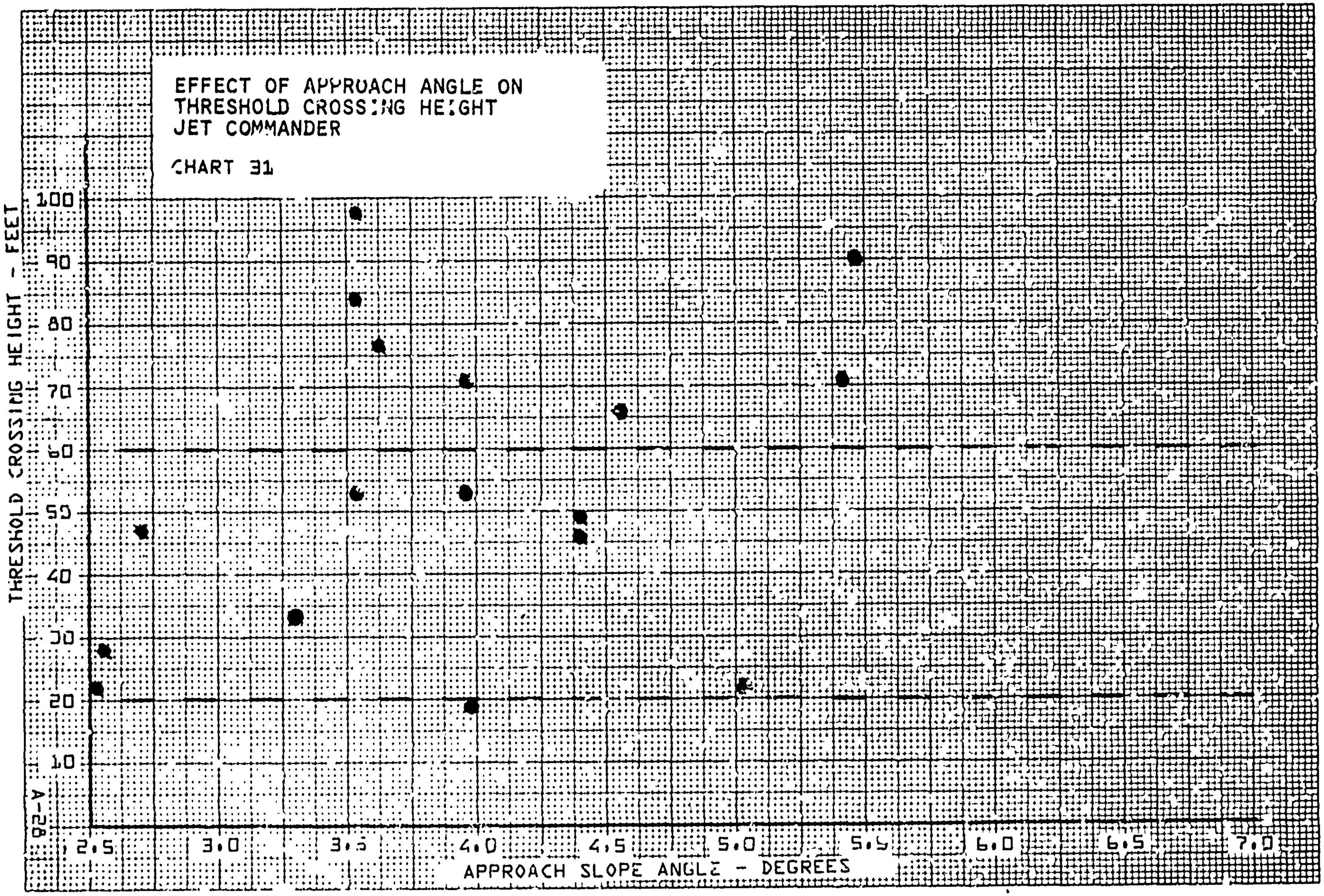
EFFECT OF APPROACH ANGLE ON
SINK RATE AT THRESHOLD
SABRELINER
CHART 28
SINK RATE AT THRESHOLD - FEET/MIN
1400
1300
1200
1100
1000
900
800
700
600
500
400
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES



EFFECT OF APPROACH ANGLE ON SINK RATE AT THRESHOLD
JETSTAR

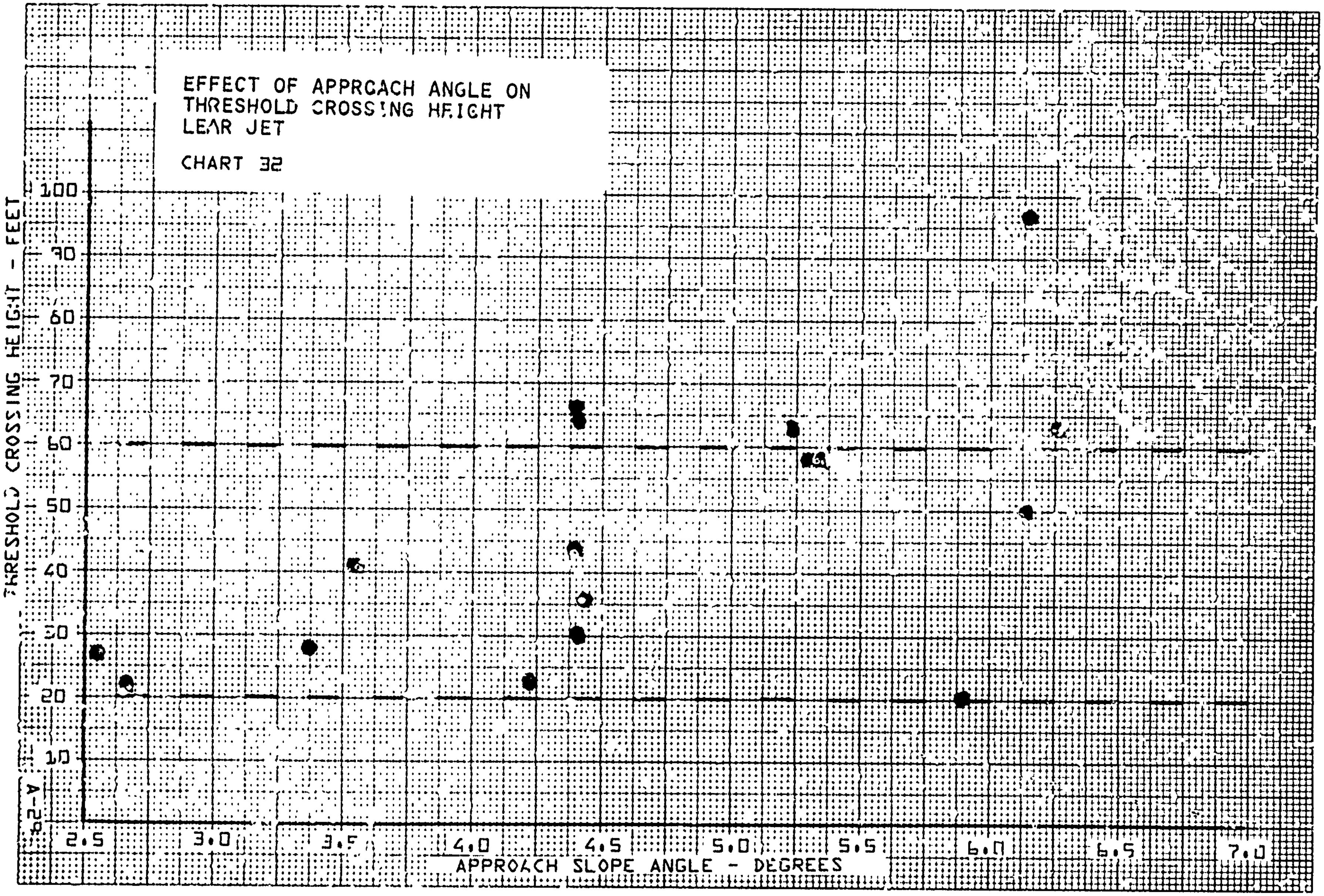
CHART 29

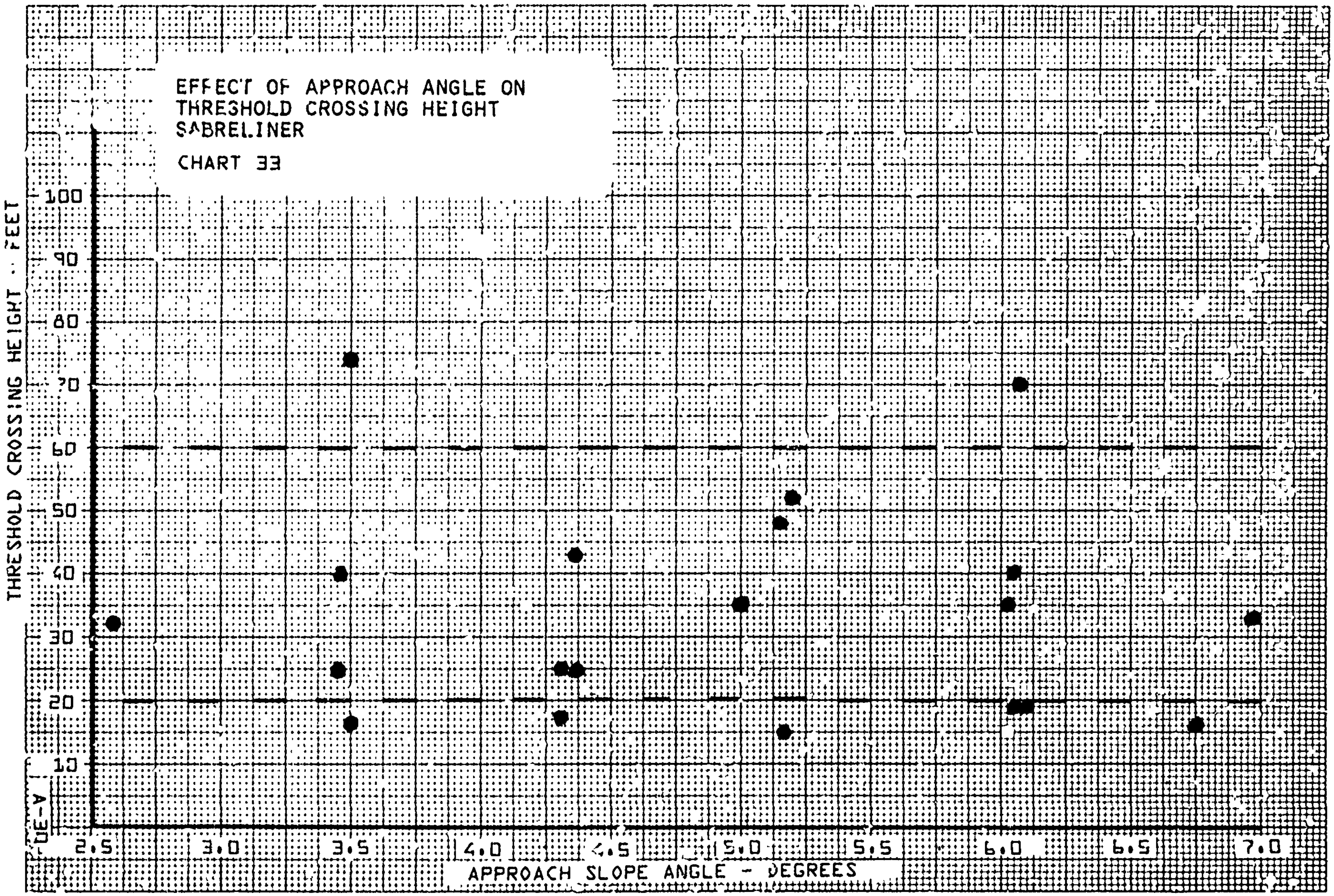

EFFECT OF APPROACH ANGLE ON
SINK RATE AT THRESHOLD
ALL AIRCRAFT
CHART 30
SINK RATE AT THRESHOLD - FEET/MIN
1400
1300
1200
1100
1000
900
800
700
600
500
400
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

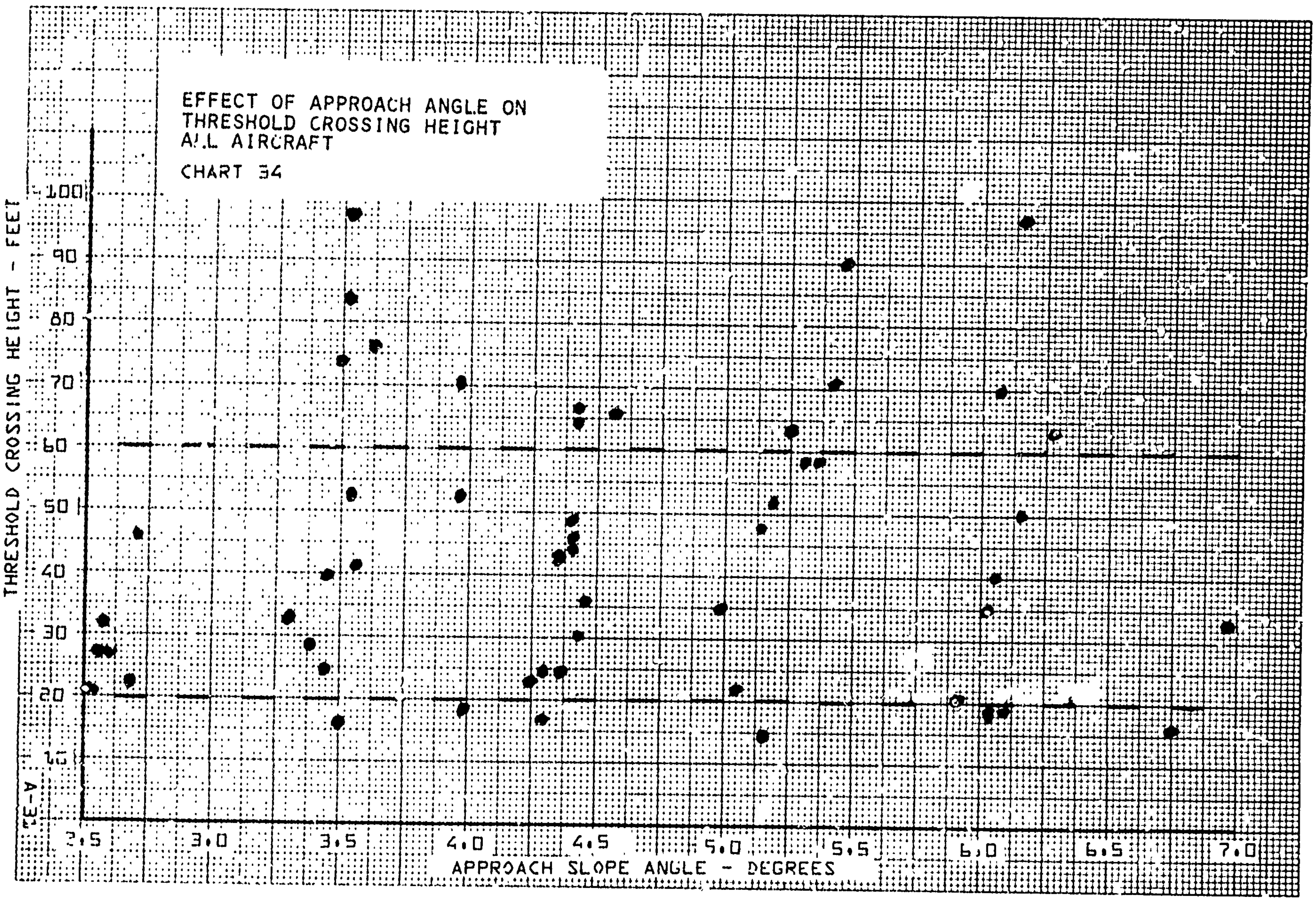


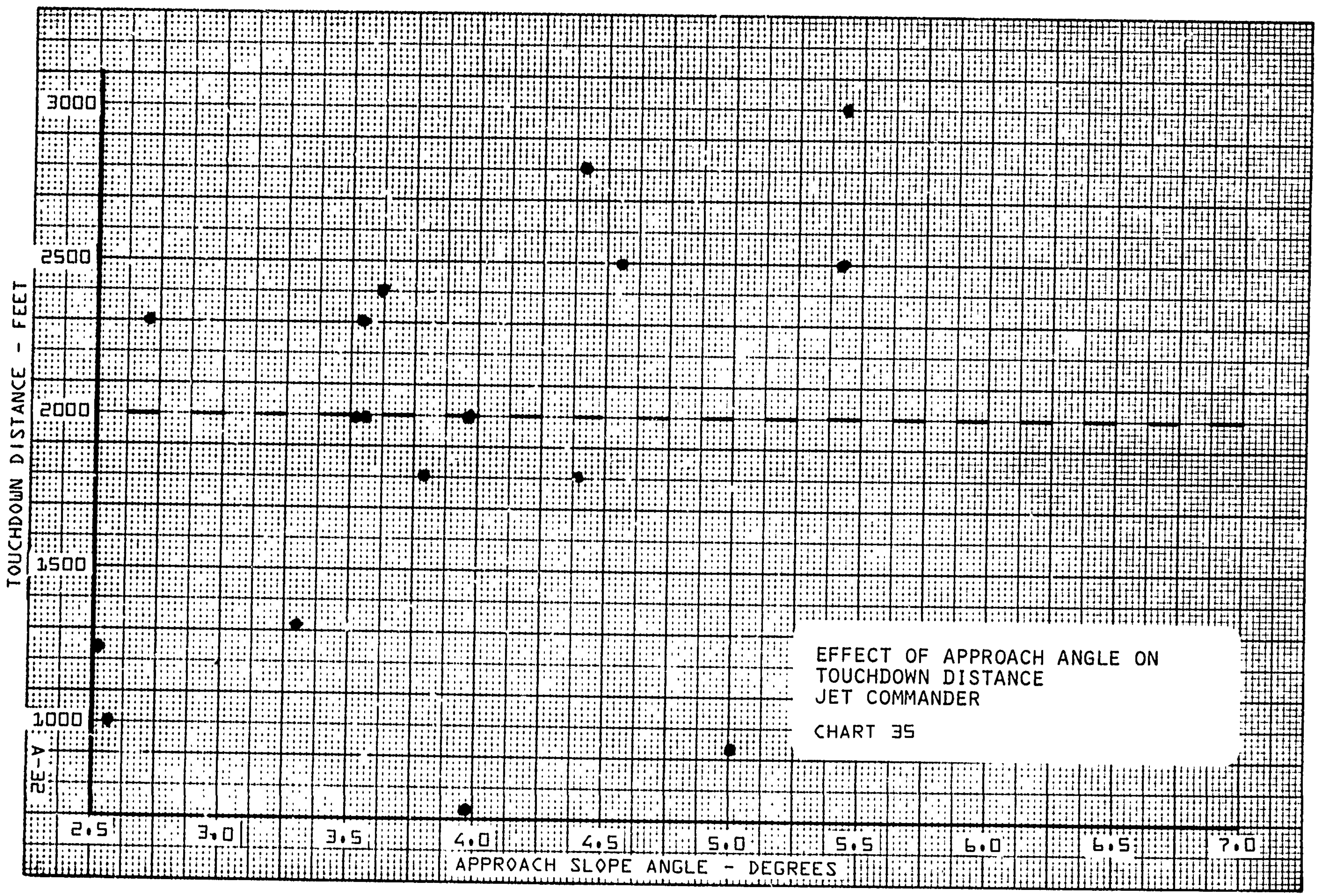
EFFECT OF APPROACH ANGLE ON
THRESHOLD CROSSING HEIGHT
JET COMMANDER
CHART 31
THRESHOLD CROSSING HEIGHT - FEET
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

A-28

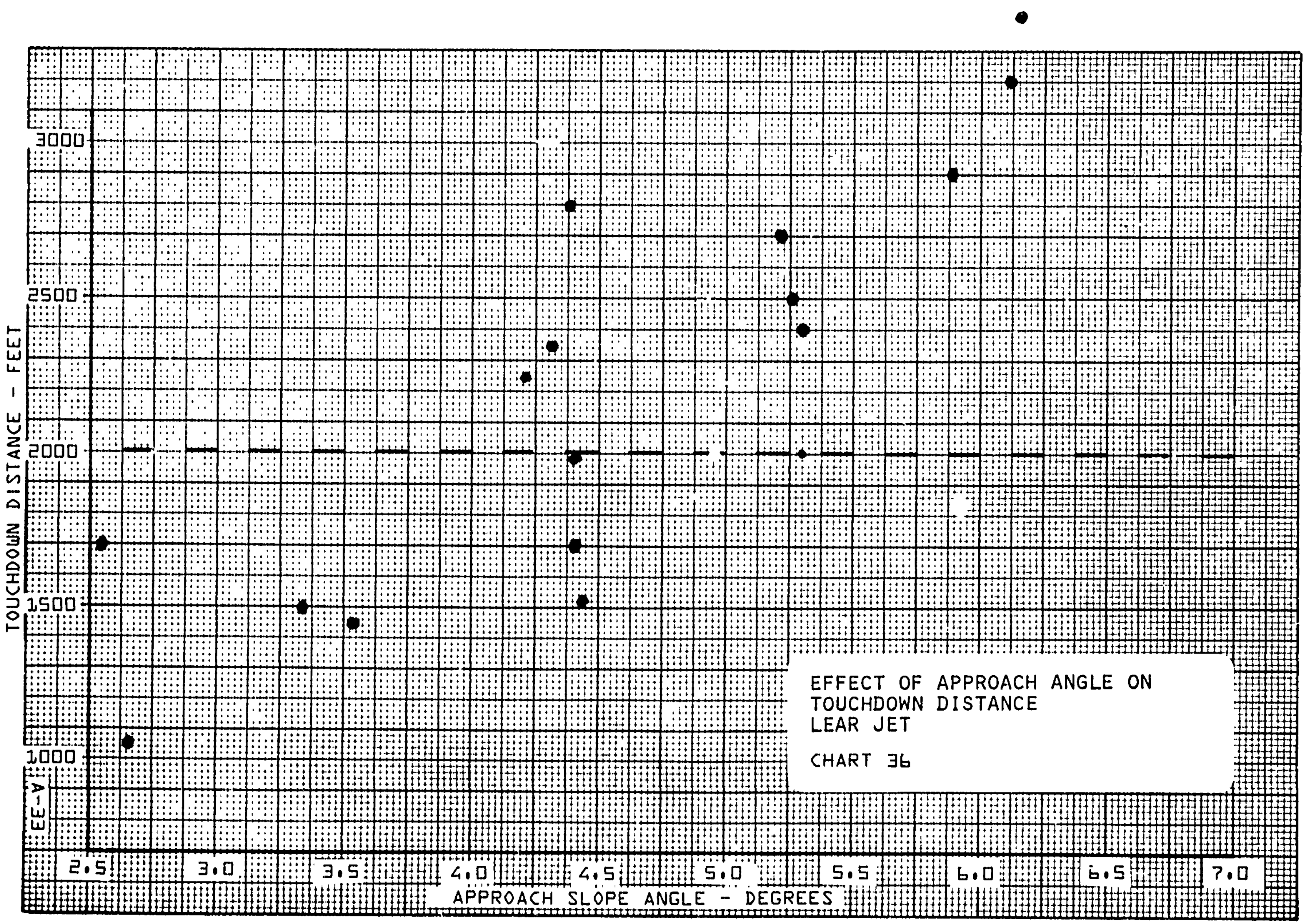

EFFECT OF APPROACH ANGLE ON
THRESHOLD CROSSING HEIGHT
LEAR JET
CHART 32
THRESHOLD CROSSING HEIGHT - FEET
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

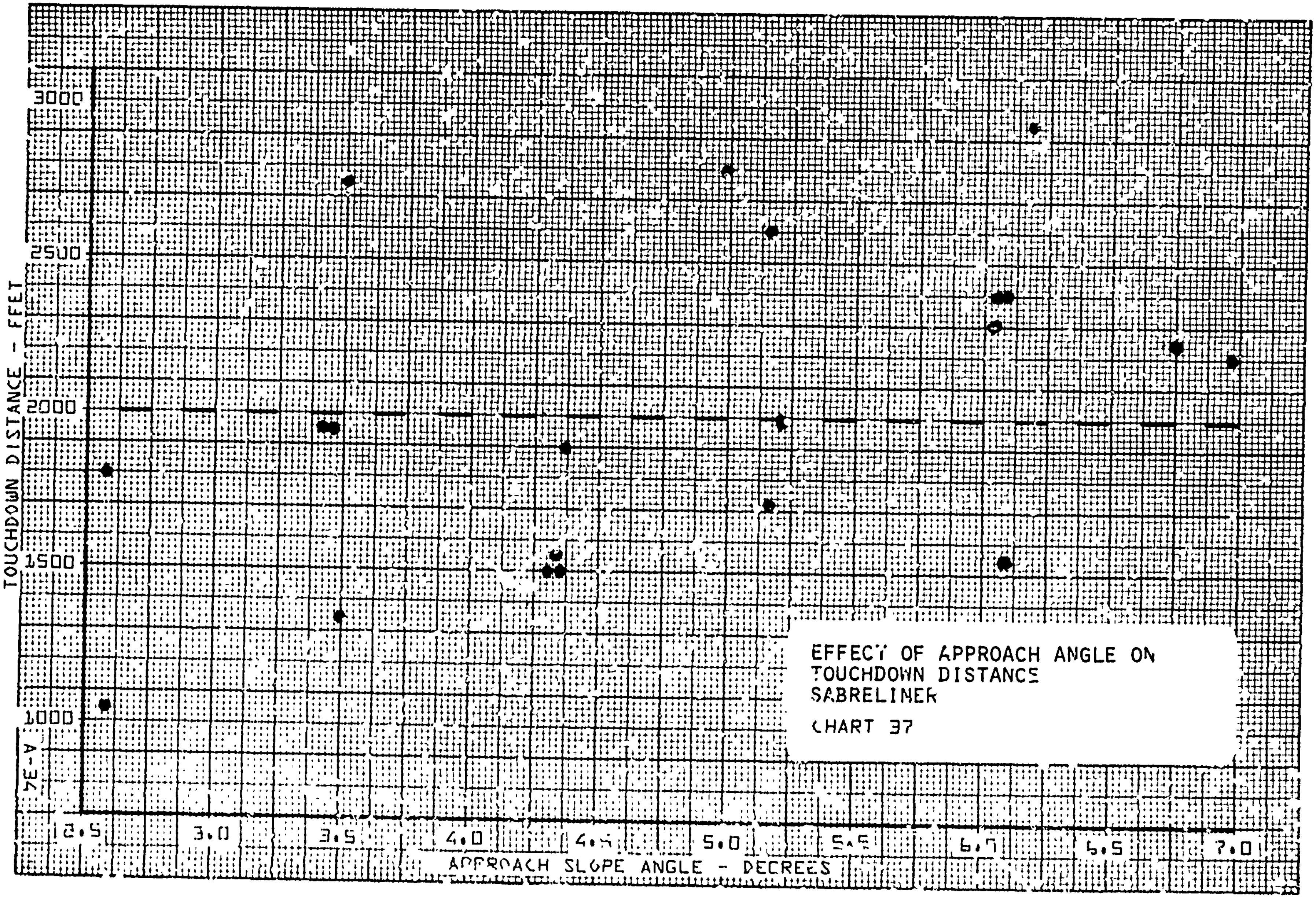

EFFECT OF APPROACH ANGLE ON
THRESHOLD CROSSING HEIGHT
SABRELINER
CHART 33
THRESHOLD CROSSING HEIGHT - FEET
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


EFFECT OF APPROACH ANGLE ON
THRESHOLD CROSSING HEIGHT
ALL AIRCRAFT
CHART 34
THRESHOLD CROSSING HEIGHT - FEET
100
90
80
70
60
50
40
30
20
10
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES



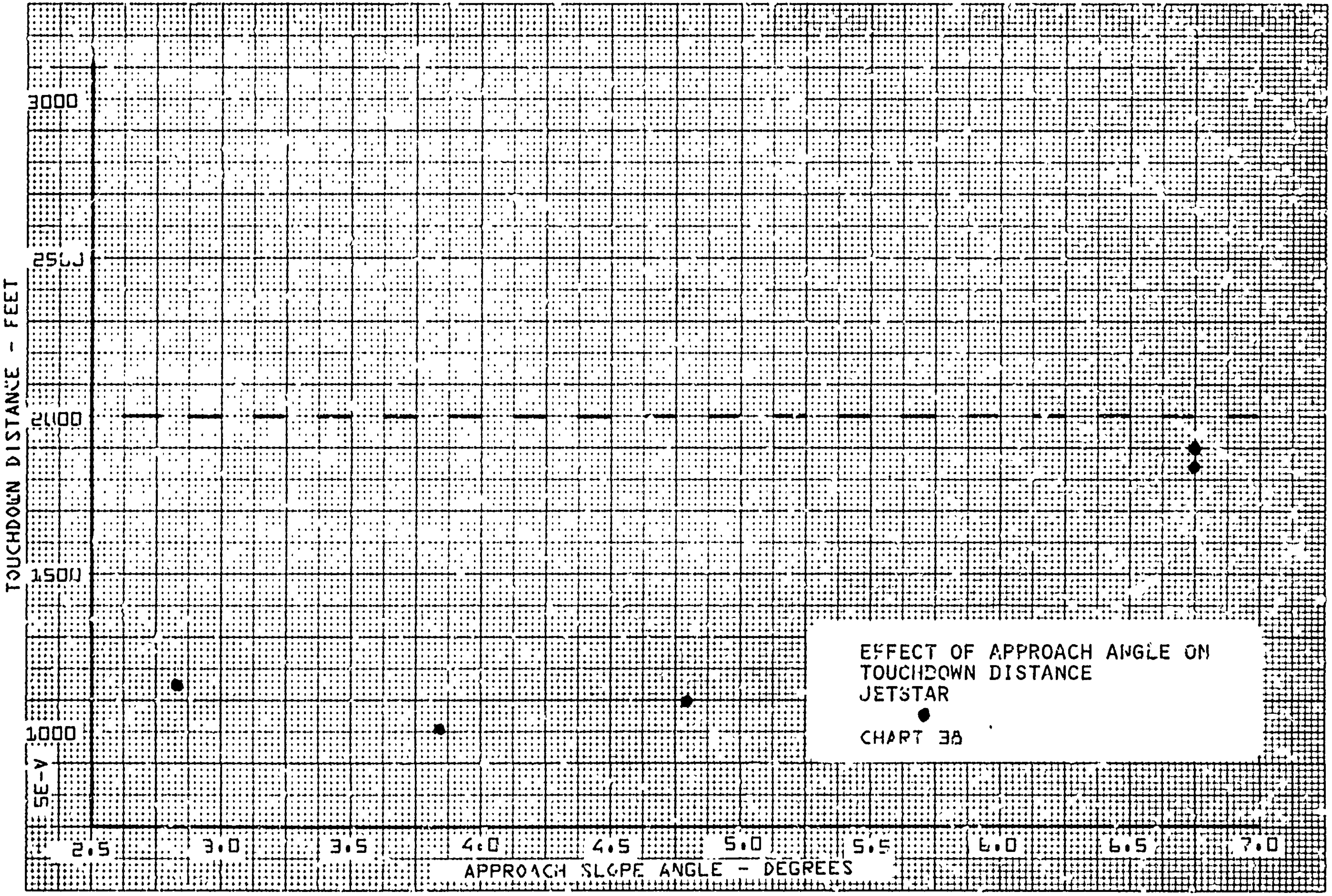
EFFECT OF APPROACH ANGLE ON
TOUCHDOWN DISTANCE
JET COMMANDER
CHART 35
TOUCHDOWN DISTANCE - FEET
3000
2500
2000
1500
1000
APPROACH SLOPE ANGLE - DEGREES
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0


EFFECT OF APPROACH ANGLE ON
TOUCHDOWN DISTANCE
LEAR JET
CHART 36
TOUCHDOWN DISTANCE - FEET
3000
2500
2000
1500
1000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

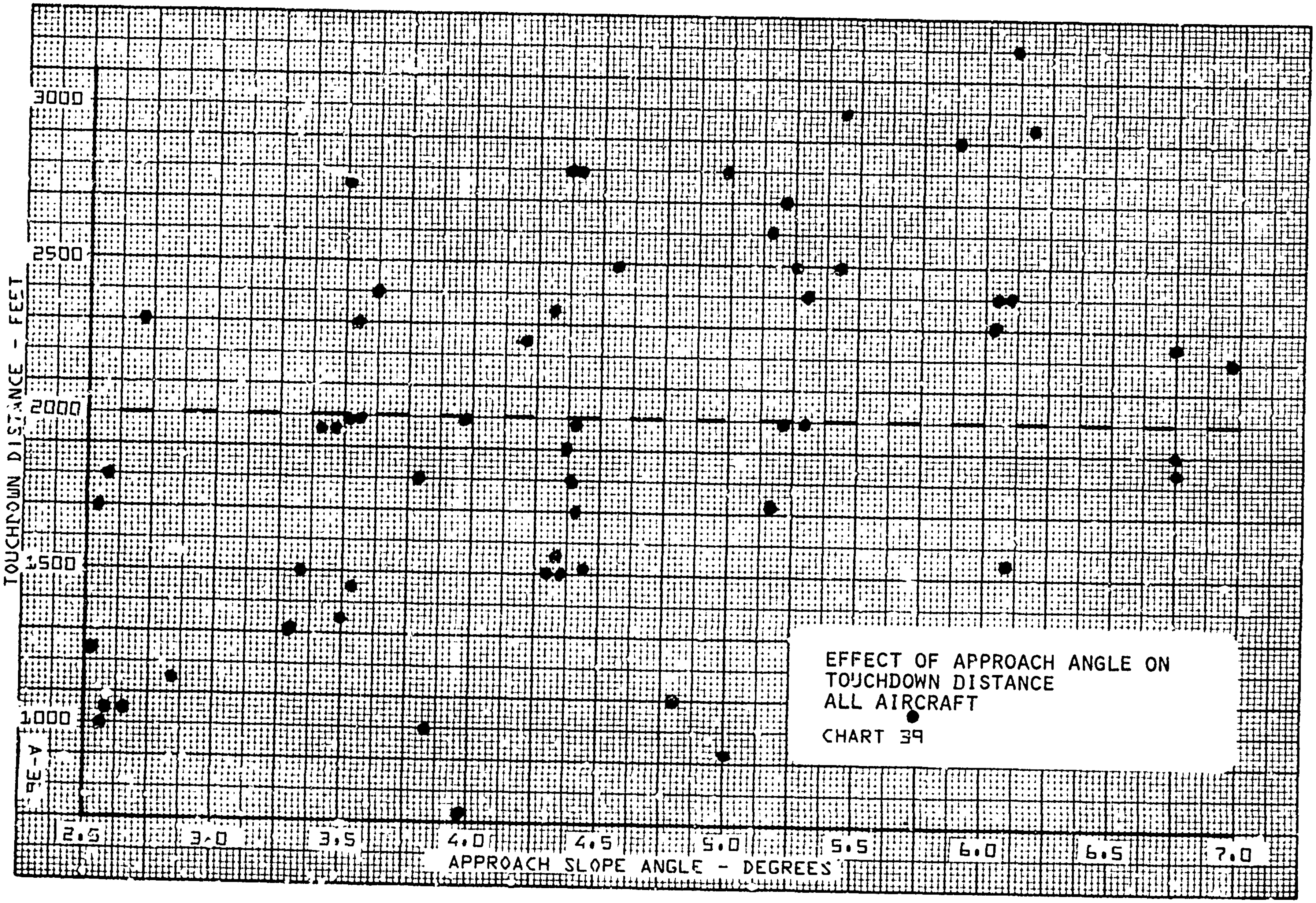


EFFECT OF APPROACH ANGLE ON
TOUCHDOWN DISTANCE
SABRELINER
CHART 37
TOUCHDOWN DISTANCE - FEET
3000
2500
2000
1500
1000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

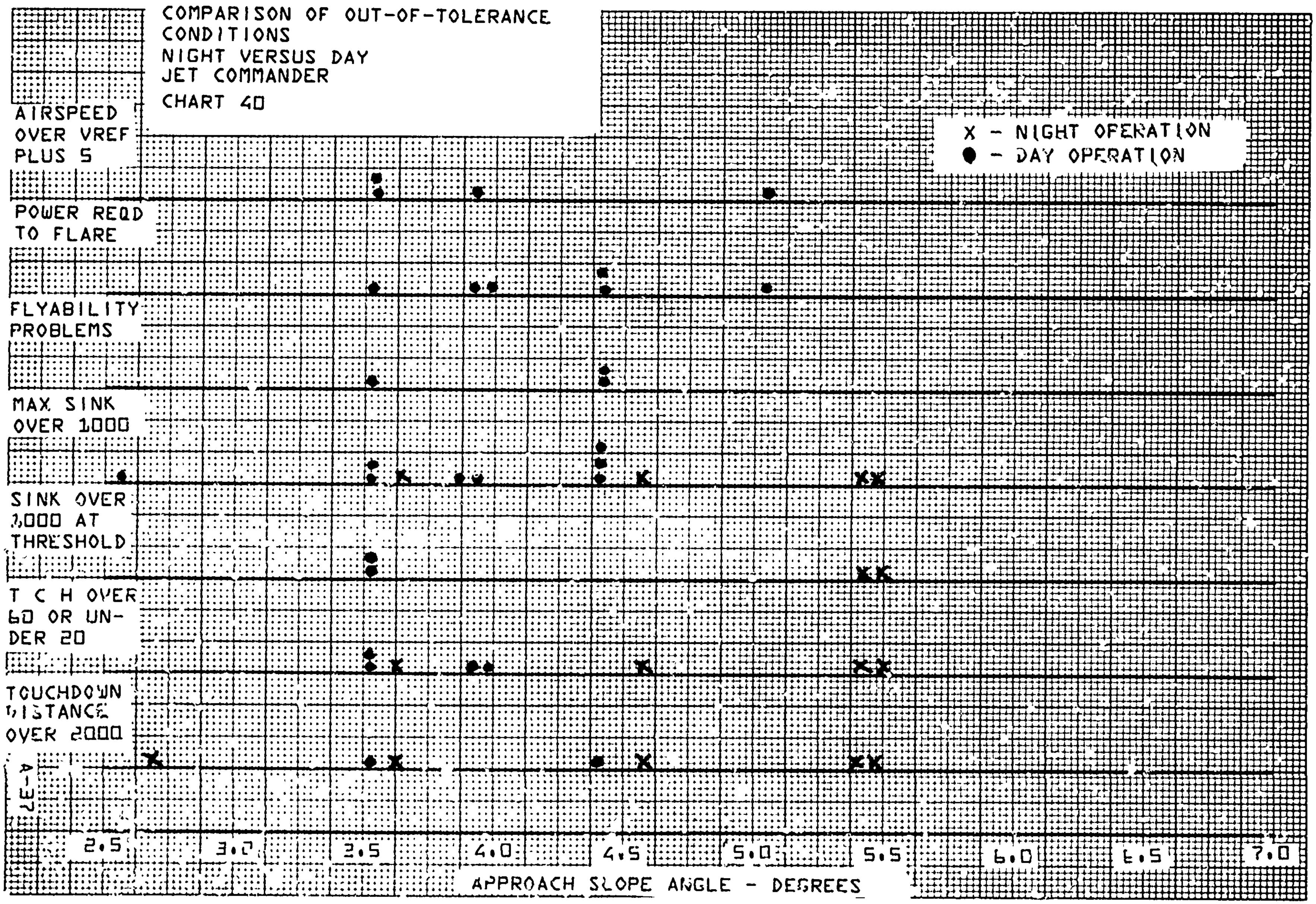
A-34



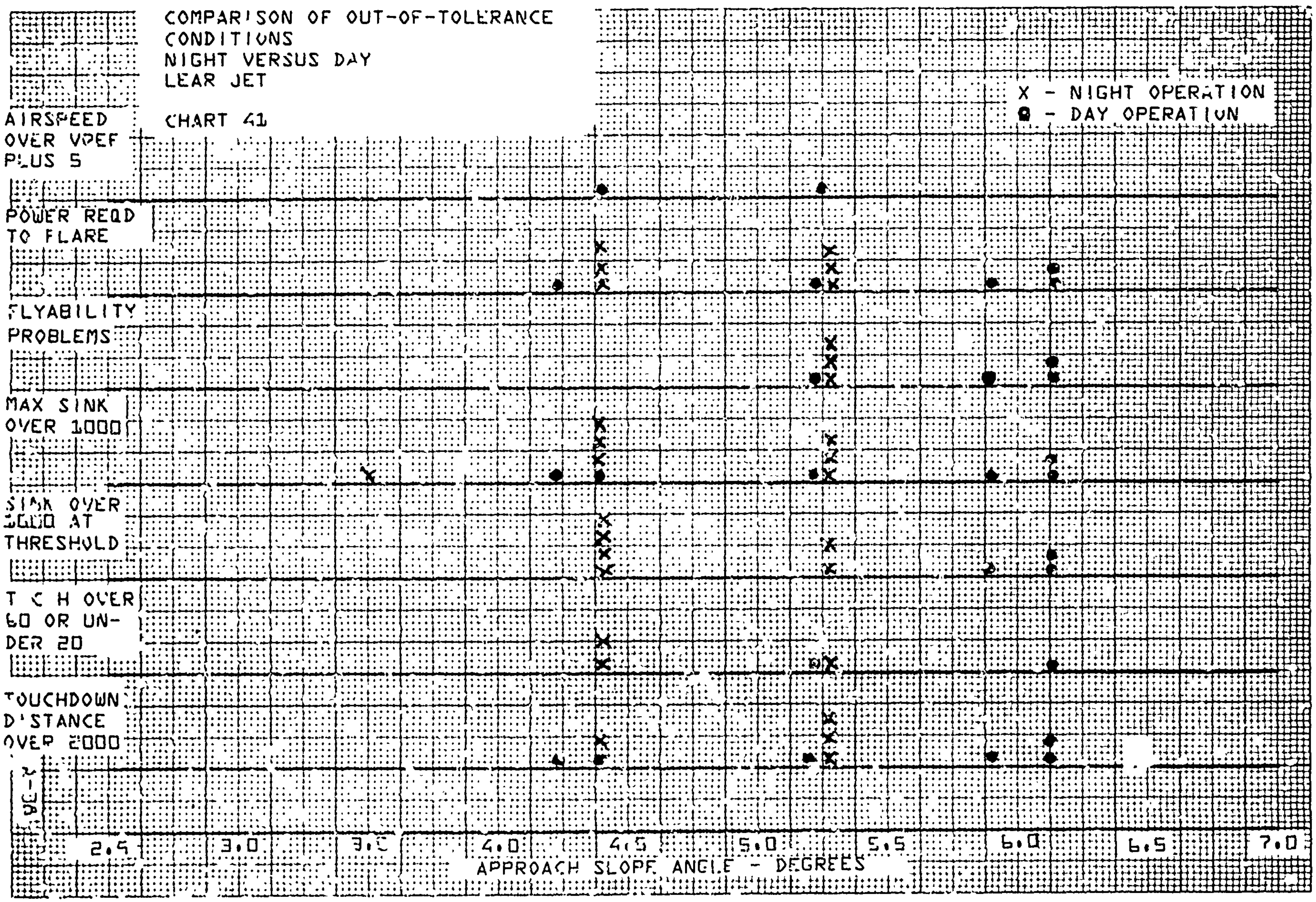
EFFECT OF APPROACH ANGLE ON
TOUCHDOWN DISTANCE
JETSTAR
CHART 3B
TOUCHDOWN DISTANCE - FEET
3000
2500
2000
1500
1000
APPROACH SLOPE ANGLE - DEGREES
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0



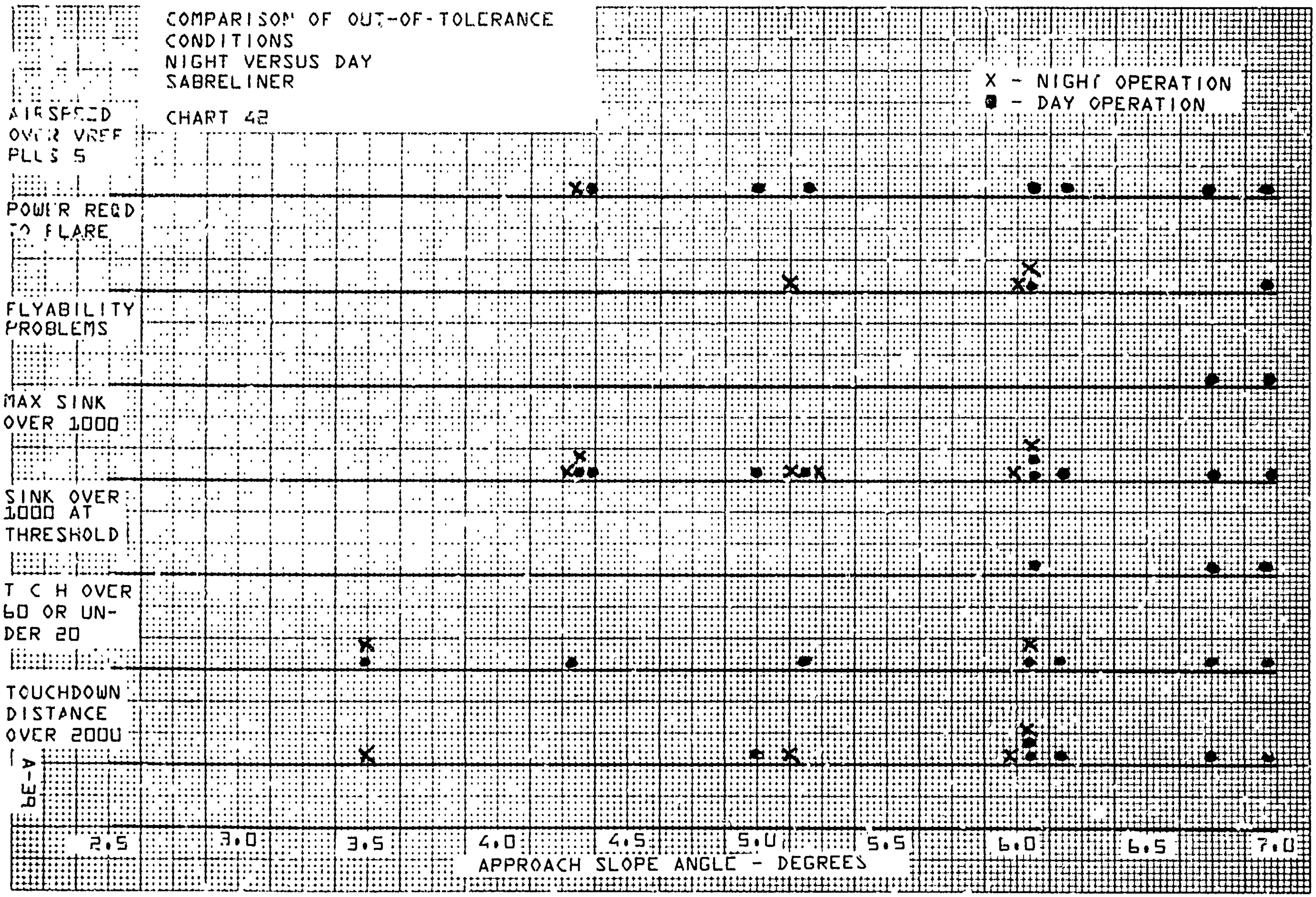
EFFECT OF APPROACH ANGLE ON
TOUCHDOWN DISTANCE
ALL AIRCRAFT
CHART 39
TOUCHDOWN DISTANCE - FEET
3000
2500
2000
1500
1000
APPROACH SLOPE ANGLE - DEGREES
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0

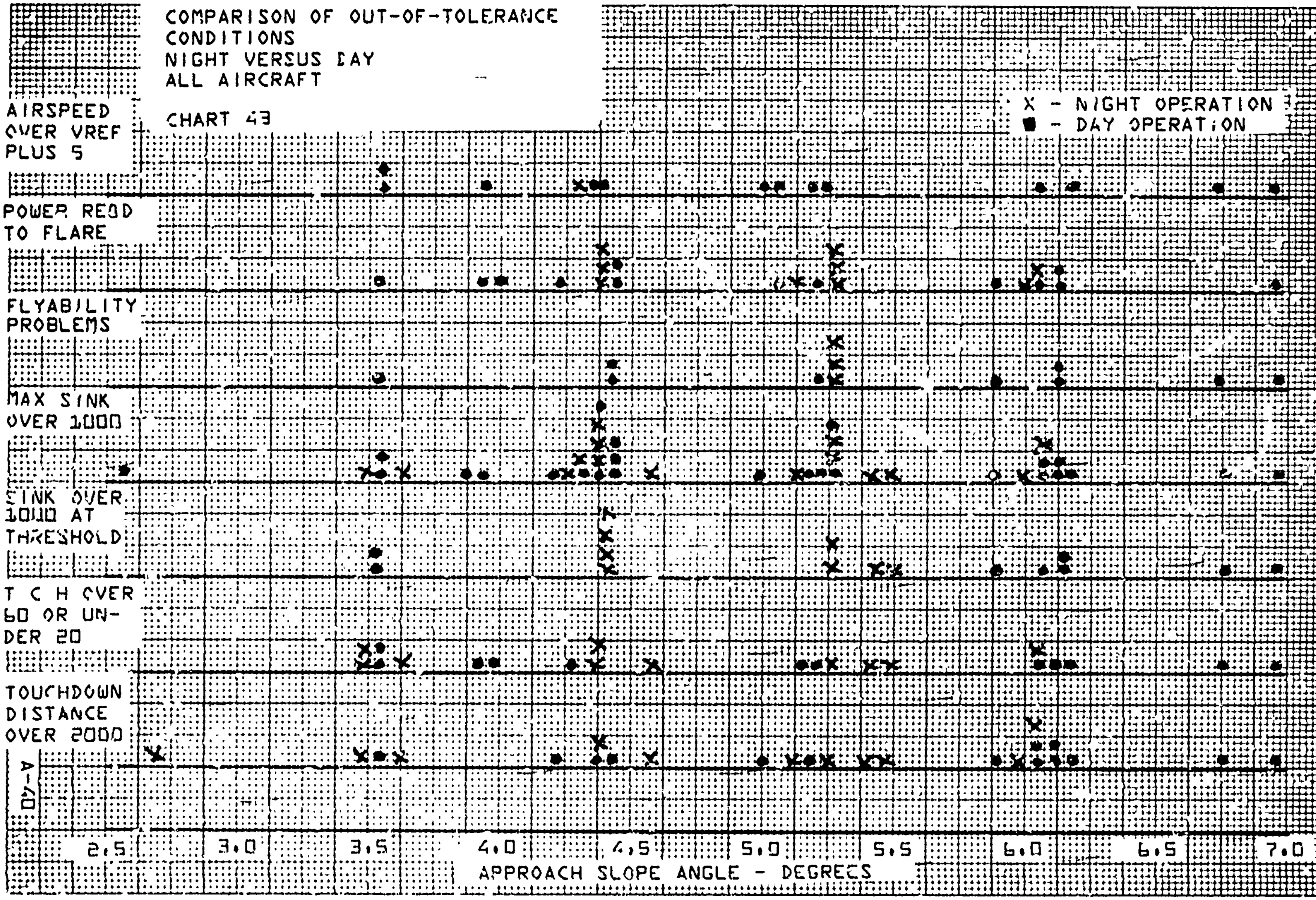


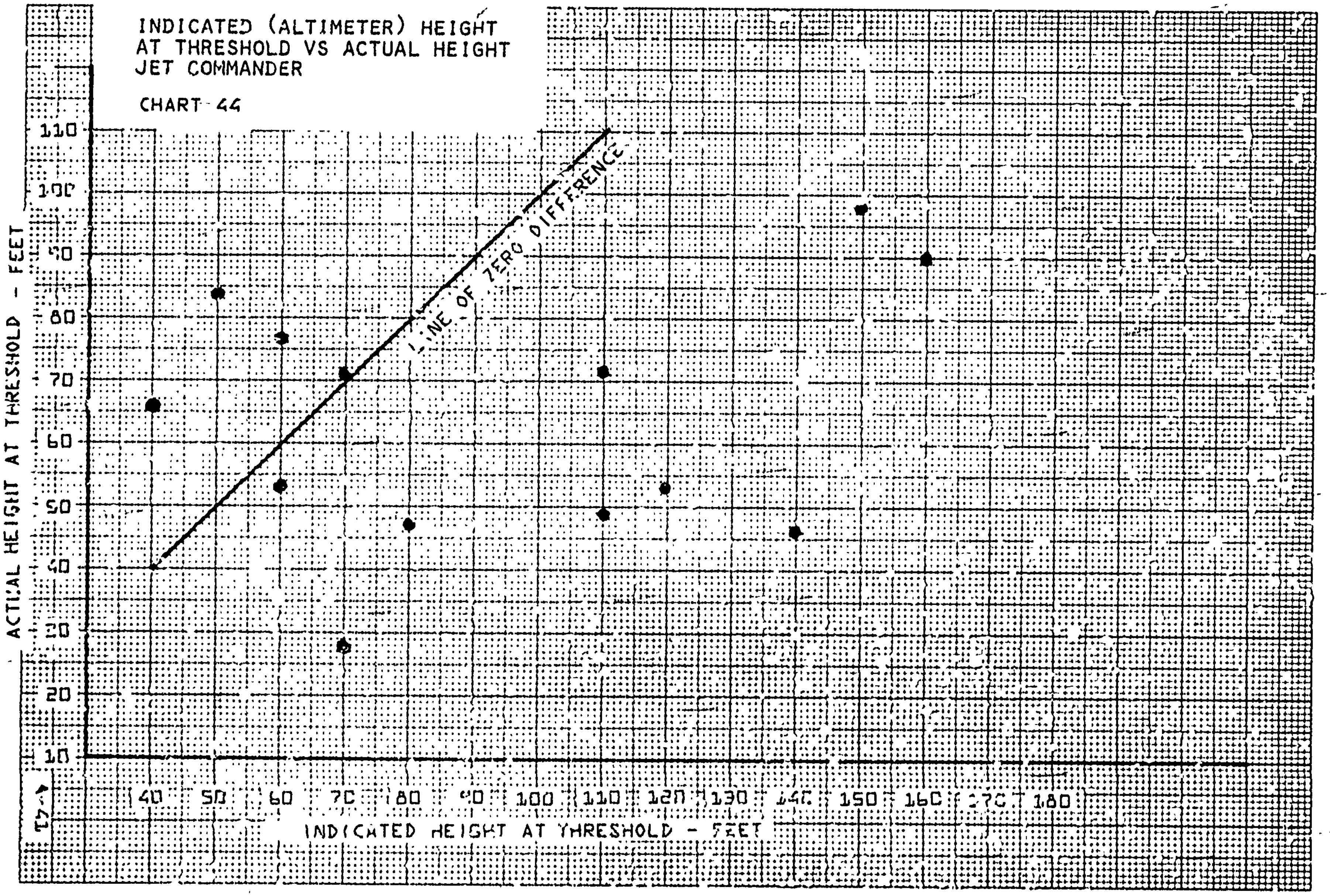
COMPARISON OF OUT-OF-TOLERANCE
CONDITIONS
NIGHT VERSUS DAY
JET COMMANDER
CHART 40
X - NIGHT OPERATION
● - DAY OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

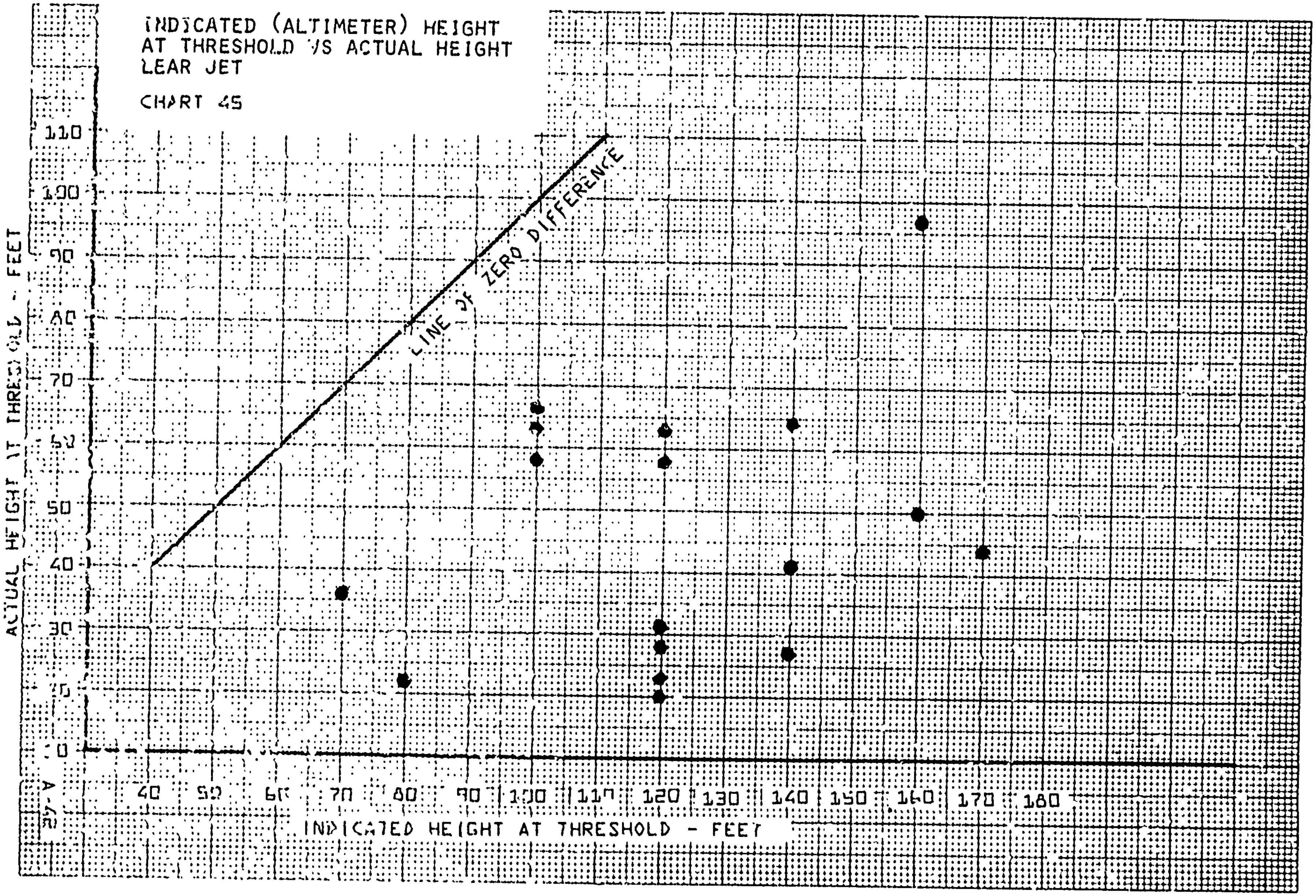


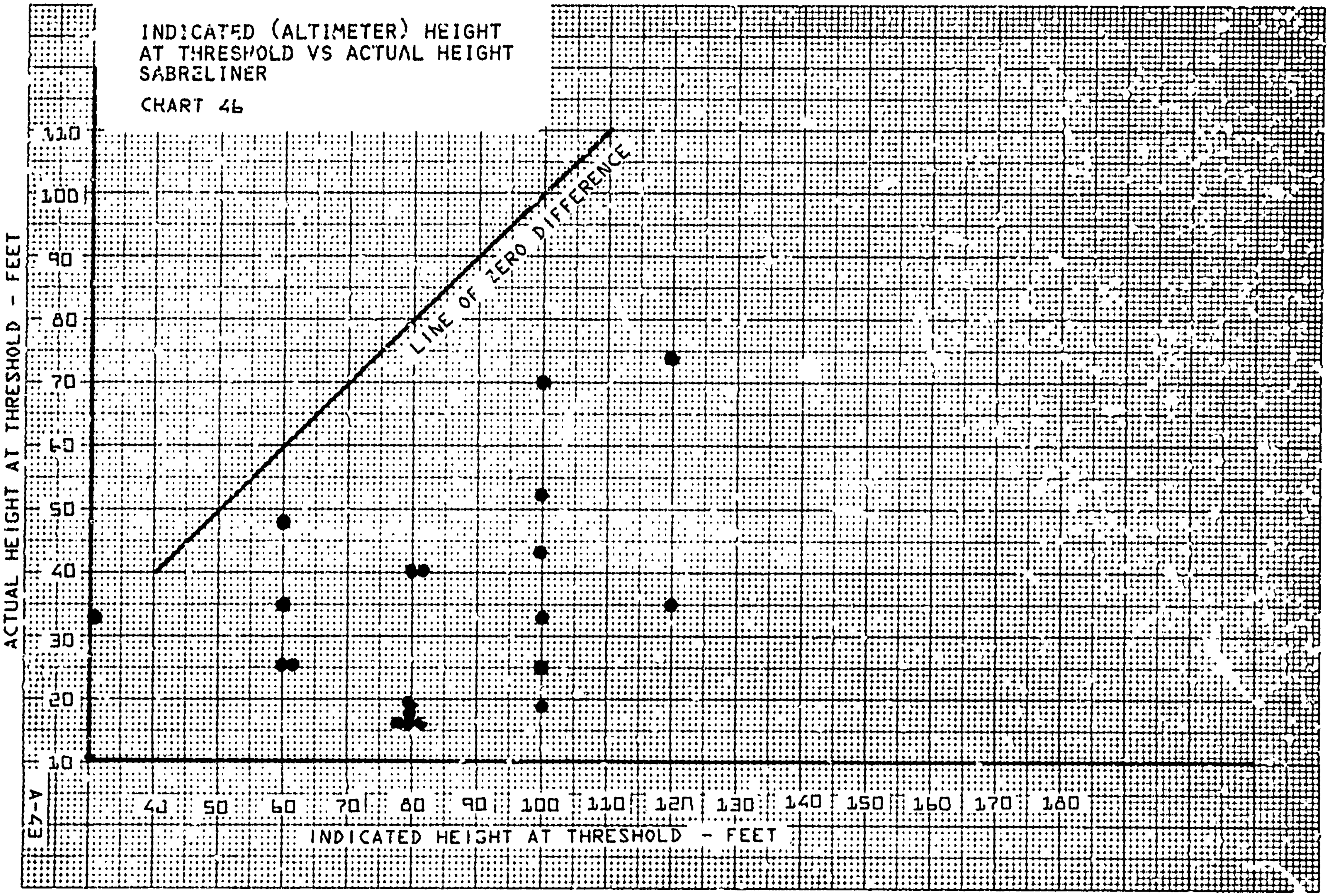
COMPARISON OF OUT-OF-TOLERANCE
CONDITIONS
NIGHT VERSUS DAY
LEAR JET
CHART 41
X - NIGHT OPERATION
● - DAY OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


COMPARISON OF OUT-OF-TOLERANCE
CONDITIONS
NIGHT VERSUS DAY
SABRELINER
CHART 42
X - NIGHT OPERATION
● - DAY OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES


COMPARISON OF OUT-OF-TOLERANCE
CONDITIONS
NIGHT VERSUS DAY
ALL AIRCRAFT
CHART 43
X - NIGHT OPERATION
■ - DAY OPERATION
AIRSPEED OVER VREF PLUS 5
POWER REQD TO FLARE
FLYABILITY PROBLEMS
MAX SINK OVER 1000
SINK OVER 1000 AT THRESHOLD
T C H OVER 60 OR UNDER 20
TOUCHDOWN DISTANCE OVER 2000
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES

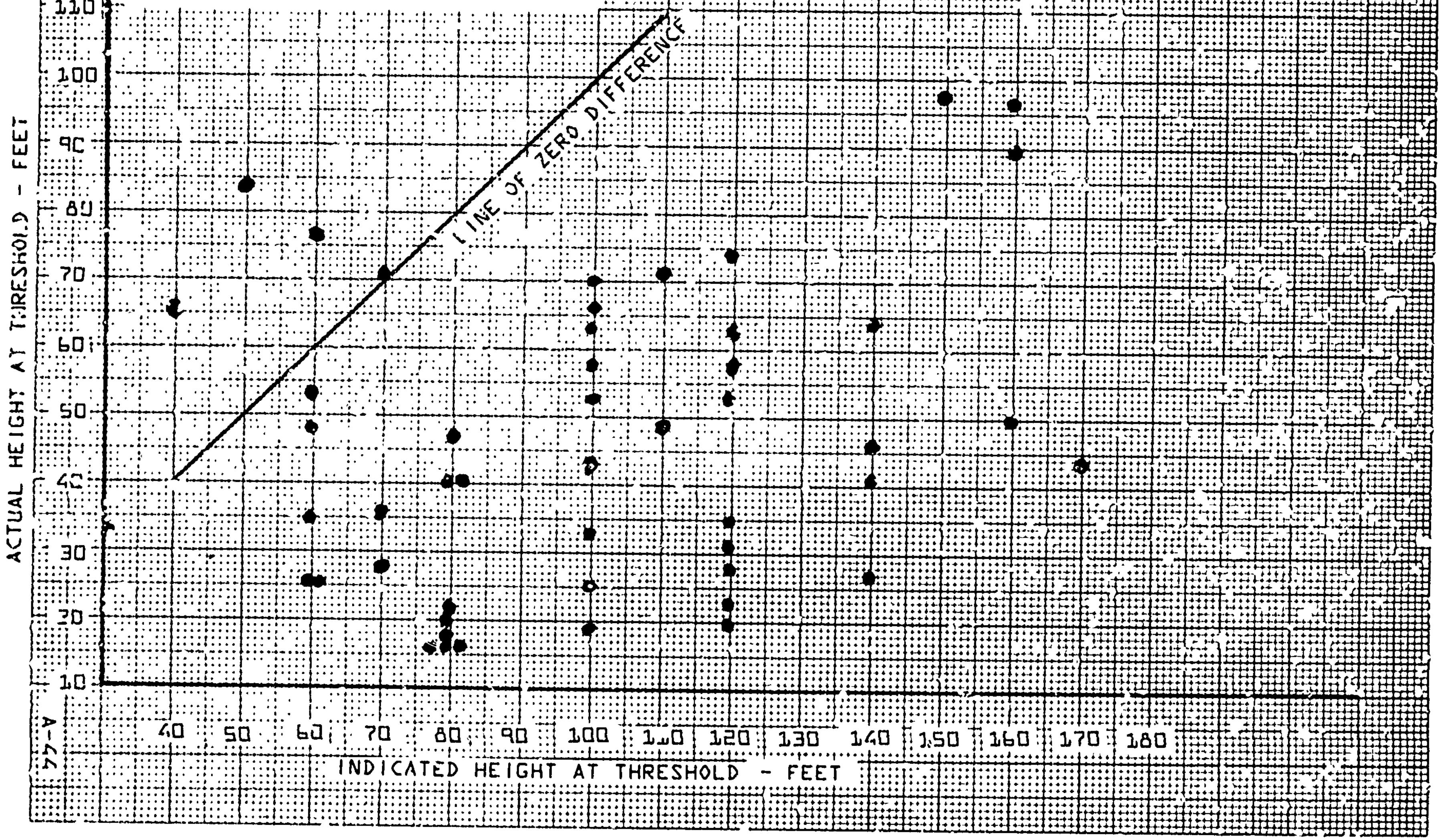

INDICATED (ALTIMETER) HEIGHT
AT THRESHOLD VS ACTUAL HEIGHT
JET COMMANDER
CHART 44
LINE OF ZERO DIFFERENCE
ACTUAL HEIGHT AT THRESHOLD - FEET
INDICATED HEIGHT AT THRESHOLD - FEET
110
100
80
70
60
50
40
20
10
40
50
60
100
110
130
150
180

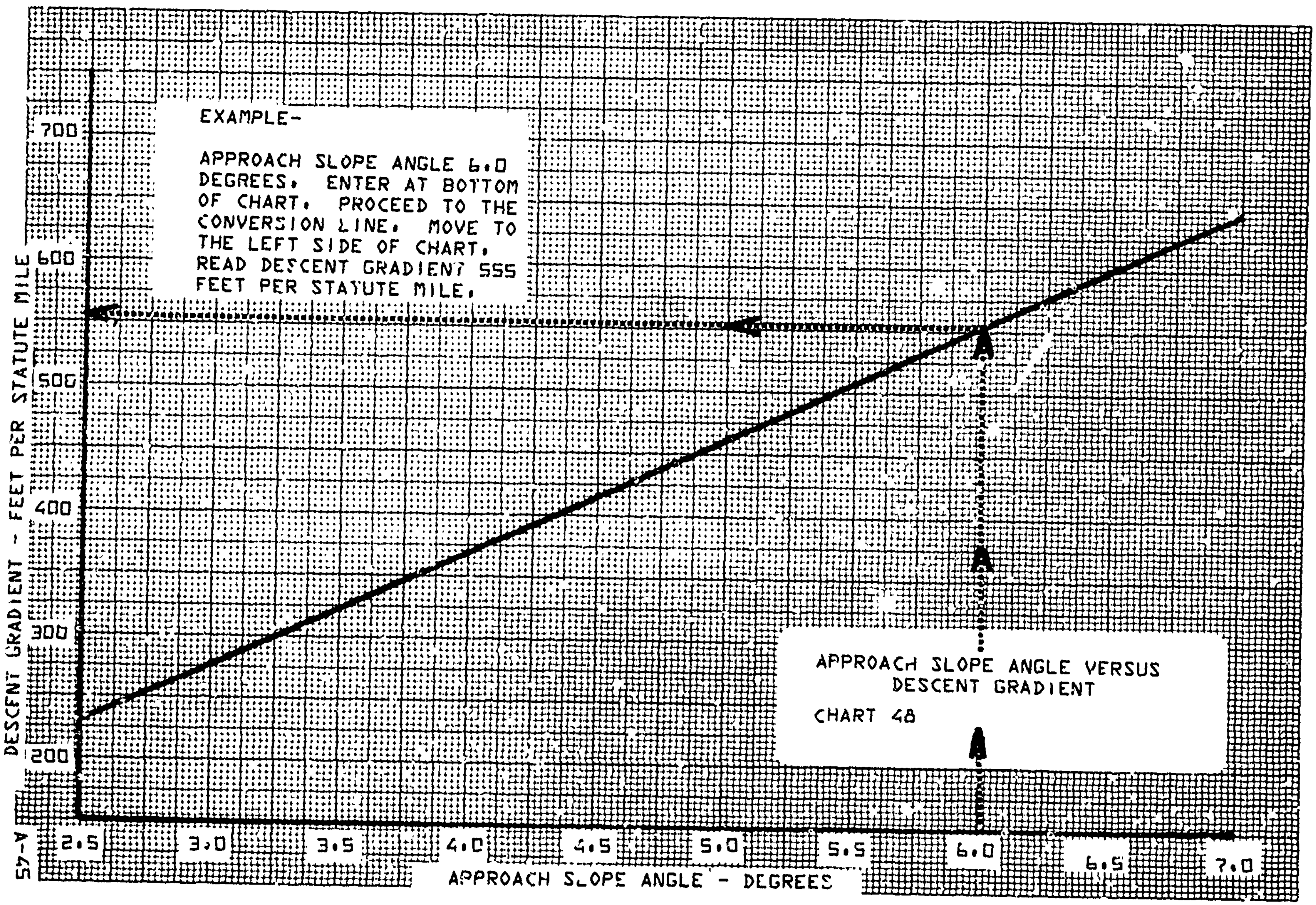

INDICATED (ALTIMETER) HEIGHT
AT THRESHOLD VS ACTUAL HEIGHT
LEAR JET
CHART 45
LINE OF ZERO DIFFERENCE
ACTUAL HEIGHT AT THRESHOLD - FEET
110
100
90
80
70
60
50
40
30
20
0
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
INDICATED HEIGHT AT THRESHOLD - FEET


INDICATED (ALTIMETER) HEIGHT
AT THRESHOLD VS ACTUAL HEIGHT
SABRELINER
CHART 46
LINE OF ZERO DIFFERENCE
ACTUAL HEIGHT AT THRESHOLD - FEET
10
20
30
40
50
60
70
80
90
100
110
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
INDICATED HEIGHT AT THRESHOLD - FEET

INDICATED (ALTIMETER) HEIGHT AT THRESHOLD VS ACTUAL HEIGHT ALL AIRCRAFT

CHART 42




EXAMPLE-
APPROACH SLOPE ANGLE 6.0 DEGREES. ENTER AT BOTTOM OF CHART. PROCEED TO THE CONVERSION LINE. MOVE TO THE LEFT SIDE OF CHART. READ DESCENT GRADIENT 555 FEET PER STATUTE MILE.
APPROACH SLOPE ANGLE VERSUS
DESCENT GRADIENT
CHART 48
DESCENT GRADIENT - FEET PER STATUTE MILE
700
600
500
400
300
200
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
APPROACH SLOPE ANGLE - DEGREES